Dry grasslands in the Western Carpathians and the northern Pannonian Basin: a numerical classification

Xerotermné trávnaté porasty Západných Karpát a severnej časti Panónskej kotliny: numerická klasifikácia

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A syntaxonomical revision of dry grasslands of the alliances *Bromo pannonici-Festucion pallentis*, *Festucion valesiacae* and *Koelerio-Phleion phleoidis* (class *Festuco-Brometea*) in the natural biogeographical region of the Western Carpathians and northern Pannonian Basin is presented. A geographically stratified data set of 2686 relevés from the south-eastern Czech Republic, north-eastern Austria, Slovakia and northern Hungary was divided into 25 clusters using a modified TWINSPAN algorithm. The proposed classification simplifies and unifies the previous syntaxonomical systems, which differ in these four countries. Main environmental gradients responsible for variation in species composition of theses grasslands were revealed by detrended correspondence analysis and interpreted using indicator values. The major pattern of variation reflects soil nutrient availability and moisture, which are negatively correlated with soil reaction.

Keywords: Austria, *Bromo pannonici-Festucion pallentis*, Czech Republic, *Festucion valesiacae*, Hungary, *Koelerio-Phleion phleoidis*, TWINSPAN, Slovakia, steppe vegetation, syntaxonomy

Introduction

Dry grassland vegetation in Central Europe represents the westernmost outposts of the vast steppes of Russia and the Ukraine (Walter 1974, Bohn & Neuhäusl 2000–2003). In Central Europe, dry grasslands have existed since the Pleistocene (Frenzel et al. 1992, Kuneš et al. 2008). With climate amelioration and forest expansion in the Holocene dry grasslands became fragmented and restricted to the driest landscapes. Humans increased the distribution of dry grasslands in Central Europe by clearing forests and extensive livestock grazing. The species composition of this habitat is affected not only by environmen-

tal factors but also by the history of particular sites since the Pleistocene, including recent land use. More recently, human activity has resulted in the reduction, further fragmentation and degradation of dry grasslands due to abandonment, afforestation, ploughing and buildings (Molnár et al. 2008). However, these sites are refuges for many rare thermophilous species of plants and insects, and significantly contribute to the biodiversity of European landscapes (e.g. Ellenberg 1986, Hobohm 2005, Wallis De Vries et al. 2002).

In eastern-central European countries such as the Czech Republic, Austria, Slovakia and Hungary, phytosociological studies of dry grassland vegetation were done independently in the past, which resulted in several syntaxonomical solutions. Numerous associations and subassociations of dry grassland vegetation were described and used in the last decades (Soó 1973, Mucina & Maglocký 1985, Mucina & Kolbek 1993, Moravec et al. 1995), many of them reflecting local variations of dry grasslands within small regions. This made the classification of dry grasslands extremely confusing. The creation of national databases of phytosociological relevés (Schaminée et al. 2009) enabled and stimulated comparative studies spanning several regions. In the Czech Republic and Slovakia, new national surveys of dry grassland vegetation were undertaken recently using national phytosociological databases (Chytrý et al. 2007, Janišová et al. 2007). The results of a large-scale study describing the variability of semi-dry grasslands in Central Europe are published in Illyés et al. (2007). However, an international survey of dry grasslands in a narrow sense, i.e. the alliances *Bromo pannonici-Festucion pallentis*, *Festucion valesiacae* and *Koelerio-Phleion phleoidis*, is lacking.

The purpose of the present study is to bridge this gap for the area of the Western Carpathians and northern Pannonian Basin. Specifically, our aims are: (i) to summarize broad-scale patterns of floristic variation in dry grasslands in the study region, (ii) to develop a numerical classification of the dry grasslands within this region using a geographically stratified data set, (iii) to identify the geographical ranges and diagnostic, constant and dominant species of the main types of dry grasslands, and (iv) to relate the clusters of the numerical classification to syntaxa described in the phytosociological literature. This study is a necessary step towards the ultimate goal: the development of an international syntaxonomical typology of central European dry grasslands, in which all associations will be defined by unequivocal assignment criteria and identifiable using an automatic expert system.

Material and methods

Study area and habitats of interest

The study area includes the Western Carpathian Mts and the neighbouring colline and lowland landscapes of the northern Pannonian Basin (Fig. 1). It includes the south-eastern Czech Republic (CZ; southern Moravia), north-eastern Austria (AT; federal states of Burgenland, Lower Austria and Vienna), Slovakia (SK) and northern Hungary (HU). This area is a natural biogeographical unit at the north-western edge of the continuous zone of the Eurasian forest-steppe. The more western areas with dry grasslands, such as Carinthia (Mucina & Kolbek 1993), northern and central Bohemia (Chytrý et al. 2007), central Germany (Mahn 1965) and the Rhine valley (Korneck 1974), which are isolated from this continuous zone and lack some south-eastern and continental species, were not included.

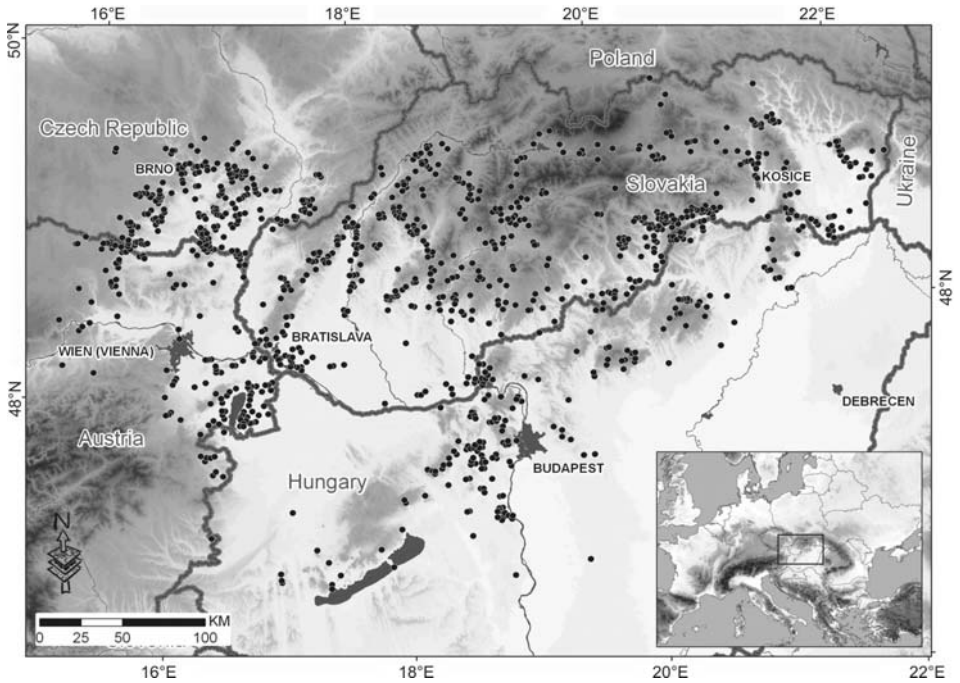


Fig. 1. – Distribution of the 2686 relevés included in the stratified data set.

The Carpathians, including the Western Carpathians, are belt-structured mountains. The Outer Western Carpathians are formed mostly of flysch rocks, such as sandstone, claystone, shale and conglomerate, the Central Western Carpathians are built of metamorphic rocks, Mesozoic crystalline carbonates and intrusive igneous rocks, and the Inner Western Carpathians consist of Neogene extrusive igneous rocks. At the boundary between the Outer and Central Western Carpathians there is a narrow (0.4 to 19 km wide) and about 600 km long zone of Mesozoic limestone cliffs called the klippen belt. The Carpathians surround the Pannonian (= Carpathian) Basin, which is filled with a thick layer of fluvial and aeolian sediments. The climate in the Carpathians and neighbouring lowlands and basins is more continental than in the Alps: precipitation is lower and the temperature range is greater (Král 1999, Miklós 2002).

The current study focuses on vegetation of the alliances *Bromo pannonici-Festucion pallentis* Zólyomi 1966 (Pannonian rocky grasslands on limestone and dolomite outcrops), *Festucion valesiacae* Klika 1931 (narrow-leaved continental basiphilous dry grasslands on shallow to deep soils) and *Koelerio-Phleion phleoidis* Korneck 1974 (acidophilous dry grasslands). Marginally, it also deals with the transitions of these vegetation types to *Sesleria*-dominated grasslands at low altitudes (*Diantho lumnitzeri-Seslerion* (Soó 1971) Chytrý et Mucina in Mucina et al. 1993), montane grasslands (*Astero alpini-Seslerion calcariae* Hadač ex Hadač et al. 1969), fringe vegetation (*Geranion sanguinei* Tüxen in Müller 1962), broad-leaved semi-dry grasslands (*Bromion erecti* Koch 1926, *Cirsio-Brachypodion pinnati* Hadač et Klika ex Klika 1951), mesic hay meadows (*Arrhenatherion elatioris* Luquet 1926) and mesic pastures (*Cynosurion cristati* Tüxen 1947) .

Vegetation data

The data for this analysis were obtained from the the Czech, Slovak and Hungarian national phytosociological databases (Chytrý & Rafajová 2003, Hegedüšová 2007, Lájer et al. 2008). The Austrian relevés of the alliances studied were mainly computerised for this purpose from data in published literature and manuscripts (http://vegedat.vinca.at). Additionally, some unpublished relevés from Hungary were used (Horváth unpubl., Kállayné Szerényi unpubl.). All relevés were made using the standard Central-European method (Zürich-Montpellier school; Braun-Blanquet 1964, Westhoff & van der Maarel 1973) between 1927 and 2007, with 48% of them made during the last two decades (1988–2007). The relevés were of plots of 4–100 m^2.

Selecting a data set that is representative of a particular syntaxonomical unit from a large phytosociological database is a methodological challenge, particularly for those units that cannot be simply delimited using a particular dominant species, such as dry grasslands. In order to obtain a data set representative of the *Bromo pannonici-Festucion pallentis*, *Festucion valesiacae* and *Koelerio-Phleion phleoidis* alliances relevés were selected from a large initial database of more than 10,600 relevés, which included all the types of grassland vegetation in the study area. Relevés with cover values > 5% of *Bothriochloa ischaemum*, *Carex humilis*, *Festuca pallens*, *F. pseudodalmatica*, *F. pseudovina*, *F. valesiaca*, *Koeleria macrantha* or *Stipa* spp. were selected because these species frequently attain high cover in the target alliances but rarely in other alliances. Diagnostic species in this target group of relevés were identified, i.e. species that were positively associated with this group in the data set of all 10,600 grassland relevés. For this purpose, a statistical measure of association of each species with the target group of relevés was calculated based on species presence/absence within and outside this group, using the phi coefficient as a fidelity measure and excluding all the statistical associations that were not significant at $P < 0.001$ based on Fisher's exact test (Chytrý et al. 2002). Then those relevés that contained ≥ 7 out of the 20 species that were most closely associated with the target group were added to the target group. The final data set consisted of 78% of the relevés selected according to dominance of the above-mentioned graminoid species and 22% of those chosen according to the presence of at least seven of the most closely associated species. After this procedure, the target group contained most of the relevés in the initial database that corresponded to the traditional phytosociological delimitation of *Bromo pannonici-Festucion pallentis*, *Festucion valesiacae* and *Koelerio-Phleion phleoidis*. However, it also contained some relevés of vegetation types that did not belong to these alliances, many of which had a high cover of *Agrostis capillaris*, *Arrhenatherum elatius*, *Brachypodium pinnatum*, *Bromus erectus*, *Sesleria albicans* or *S. heufleriana*. Therefore all relevés with cover > 25% of these species and relevés assigned by their original authors to the alliance *Alysso-Festucion pallentis* Moravec in Holub et al. 1967, which represents the Hercynic vegetation of rock outcrops with *Festuca pallens,* were removed. Additionally, relevés with a tree layer cover > 20% and species-poor (in some cases probably incomplete) relevés containing < 10 species, were also excluded. These subjective but consistently applied selection criteria resulted in a data set of dry grassland vegetation dominated by narrow-leaved tussocky species, occurring on both shallow rocky soils and deeper soils, which corresponds to the traditional phytosociological delimitation of the three target alliances.

A geographical stratification (Knollová et al. 2005) of the data was done using grid cells of 10 longitudinal × 6 latitudinal minutes (i.e. approximately 12 × 11 km). In order to reduce oversampling of some small areas and obtain a data set that would be more representative of the entire study area, a maximum of 20 relevés from each grid cell were selected at random. After this stratified resampling the data set consisted of 2712 relevés. This data set was edited using the JUICE 6.5 program (Tichý 2002).

Species taxonomy and nomenclature

For the analyses we excluded taxa determined only to the genus level, bryophytes and lichens (because they were not sampled by several authors of relevés), and all tree and shrub species, except the low-growing xerophilous shrubs *Amygdalus nana*, *Cerasus fruticosa*, *Cotoneaster* spp., *Daphne cneorum*, *Rosa gallica*, *R. pimpinellifolia* and *Spiraea media*.

For numerical analyses, some taxonomically problematic species, which were not distinguished in several relevés, were classified within higher or broadly defined taxa. The species aggregates (agg.) used follow Marhold (1998); the abbreviation 's.l.' indicates groups of a few species that are difficult to distinguish, or were not distinguished in all relevés, or their taxonomy needs to be resolved (Electronic Appendix 1). For calculation of the diagnostic, constant and dominant species, some of the previously merged taxa were included in the table (*Achillea collina*, *A. pannonica*, *A. setacea*, *Festuca pseudodalmatica*, *F. valesiaca*, *Onobrychis arenaria* and *O. viciifolia*). In some relevés, these species were determined to a broader taxon, therefore the use of the narrow taxa might unduly influence numerical analyses. Nevertheless, there were many relevés in which these species were distinguished and including them in the table for the analysis of diagnostic, constant and dominant species enabled us to detect whether some of them were characteristic of certain clusters. This was particularly important in the case of *Festuca pseudodalmatica* and *F. valesiaca*, which are dominants in many types of dry grassland. Nomenclature of species and subspecies follows Marhold (1998); for taxa not included in this handbook, nomenclature is that used in other national floras (Simon 2000, Kubát et al. 2002, Fischer et al. 2005).

Relevés in each cluster were inspected and assigned to one or more phytosociological associations, based on the expert knowledge, literature sources and considering relevé assignments by their original authors (if available). Nomenclature of associations and alliances was revised according to the International Code of Phytosociological Nomenclature (Weber et al. 2000).

Data analysis

Outlier relevés were identified using detrended correspondence analysis (DCA) of log-transformed species percentage covers (CANOCO 4.5 package; ter Braak & Šmilauer 2002). Based on a visual inspection of the DCA ordination diagram 26 outlying relevés were excluded. The data set used for further analyses consisted of 2686 relevés (Fig. 1) including 552 from the Czech Republic, 330 from Austria, 1180 from Slovakia and 624 from Hungary.

Several types of agglomerative and divisive classification methods were applied, including the beta flexible linkage method with Bray-Curtis distance measure and log and square-root transformation of percentage covers, beta flexible linkage method with Sørensen distance measure and presence/absence species data, Ward's method with Euclidean distance and log-transformed covers, and TWINSPAN modified according to Roleček et al. (2009). Calculations were done using the PC-ORD 5 and JUICE 6.5 programs (McCune & Mefford 1999, Tichý 2002). After examining several partitions of the data set, the partition that produced clusters which most closely matched the established phytosociological units was accepted. The selected partition was the one produced by the modified TWINSPAN algorithm with three pseudospecies cut levels (0%, 5%, 25%) and total inertia as a measure of cluster heterogeneity. In contrast to the standard TWINSPAN (Hill 1979), in this modification of TWINSPAN the sequence of splits is determined by the internal heterogeneity of clusters and the resulting partition can have any number of clusters, not only 2, 4, 8, 16 etc. The number of clusters used for interpretation was selected subjectively but was supported by crispness (Botta-Dukát et al. 2005) and OptimClass analyses (Tichý et al. 2010). The maps documenting the geographical distribution of clusters were prepared using the DMAP program (Morton 2005).

The diagnostic species of individual clusters were determined by calculating the phi coefficient as a fidelity measure with equalization of cluster sizes according to Tichý & Chytrý (2006). The species for which the occurrence concentration in relevés of the target clusters was not significant at $P < 0.05$ (Fisher's exact text; Chytrý et al. 2002) were excluded. Species were considered as diagnostic for individual clusters if $\Phi > 0.15$, and in the species lists their names are in bold type if $\Phi > 0.30$. For determination of diagnostic species of alliances the same threshold criteria were used except that the level of significance was set at $P < 0.001$. The threshold constancy value of species to be considered as constant for clusters and alliances was set to 40% (or 60% for the species in bold). Dominant species were defined as those with a cover > 25% in > 5% of relevés (or in > 25% of relevés for species in bold). Species names in the lists are arranged alphabetically. At the highest hierarchical level, the clusters were divided into two branches (Fig. 2; branch 1: clusters 1–6, branch 2: clusters 7–25). Diagnostic species of each cluster on a branch were calculated based on a comparison with a pooled group of relevés belonging to the other branch. This means that each of the clusters 1–6 was compared to all other clusters on branch 1 and the pooled group of relevés from the clusters on branch 2 (clusters 7–25) and similarly, each of the clusters 7–25 was compared to all other clusters on branch 2 and the pooled group of relevés from the clusters on branch 1 (clusters 1–6). This comparison ensured that the lists of diagnostic species for each cluster also included diagnostic species of the higher unit.

The diagnostic, constant and dominant species of the three alliances *Bromo pannonici-Festucion pallentis* (clusters 1–6), *Festucion valesiacae* (clusters 7–14, 17, 19–25) and *Koelerio-Phleion phleoidis* (clusters 15, 16) were determined within the context of a larger data set including the stratified selection of relevés of other grassland types (*Arrhenatherion elatioris*, *Bromion erecti* and *Cirsio-Brachypodion pinnati*) occurring in the study area. Since the current analysis did not focus on semi-dry grasslands and meadows, assignment of relevés to the three last mentioned alliances followed the classification by the authors of the relevés.

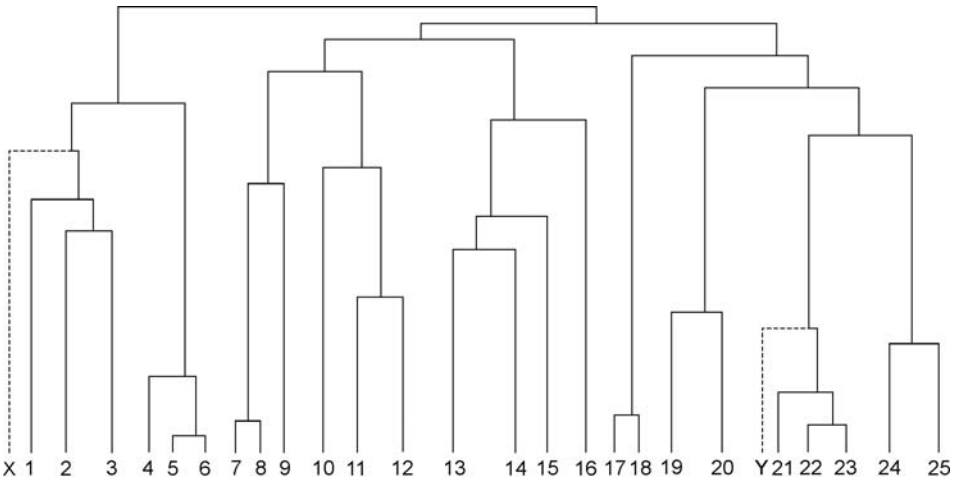


Fig. 2. – Dendrogram based on the modified TWINSPAN classification. The numbers indicate clusters; X and Y indicate local types that are not evaluated in the text. Alliances: *Bromo pannonici-Festucion pallentis* (clusters 1–6), *Festucion valesiacae* (clusters 7–14, 17 and 19–25), *Koelerio-Phleion phleoidis* (clusters 15 and 16) and *Cynosurion cristati* (cluster 18).

For environmental characterization of clusters, a DCA ordination with square-root transformation of species percentage covers was performed, using detrending by segments in the R program (R Development Core Team 2007). The mean indicator values for relevés were plotted onto the ordination diagram as supplementary variables. The indicator values of Borhidi (1993) were used, which are essentially Ellenberg indicator values modified for the Pannonian region. Indicator values of 124 species (12% of the whole data set) were not included in Borhidi (1993) and these species were also not included in the present calculations, as the resulting error is likely to be negligible when dealing with species-rich communities (Ewald 2003, Otýpková 2009). The DCA was visualized using the function 'ordispider' in the R program 'vegan' package (Oksanen et al. 2009), which draws 'spider diagrams' with each point (relevé) connected to the cluster centroid by a line. The box-and-whiskers plots comparing the clusters using Borhidi values were drawn in the STATISTICA program (StatSoft Inc. 2006).

Results

TWINSPAN divided the relevés into 27 clusters (Fig. 2) arranged along a gradient of soil nutrient availability, which is positively correlated with moisture and negatively with soil reaction. The predominance of these factors was confirmed by ordination (Fig. 3). Of the three groups of clusters at the top of the classification hierarchy, group 1 (clusters 1–6) includes open grasslands on very dry and shallow soil that develop on base-rich rocky outcrops. Group 2 (clusters 7–16) represents semi-closed grasslands at dry and warm sites with a moderately deep layer of rocky soil, which are called "slope steppes" in Hungarian phytosociological literature (Zólyomi 1958, Illyés & Bölöni 2007). Group 3 (clusters

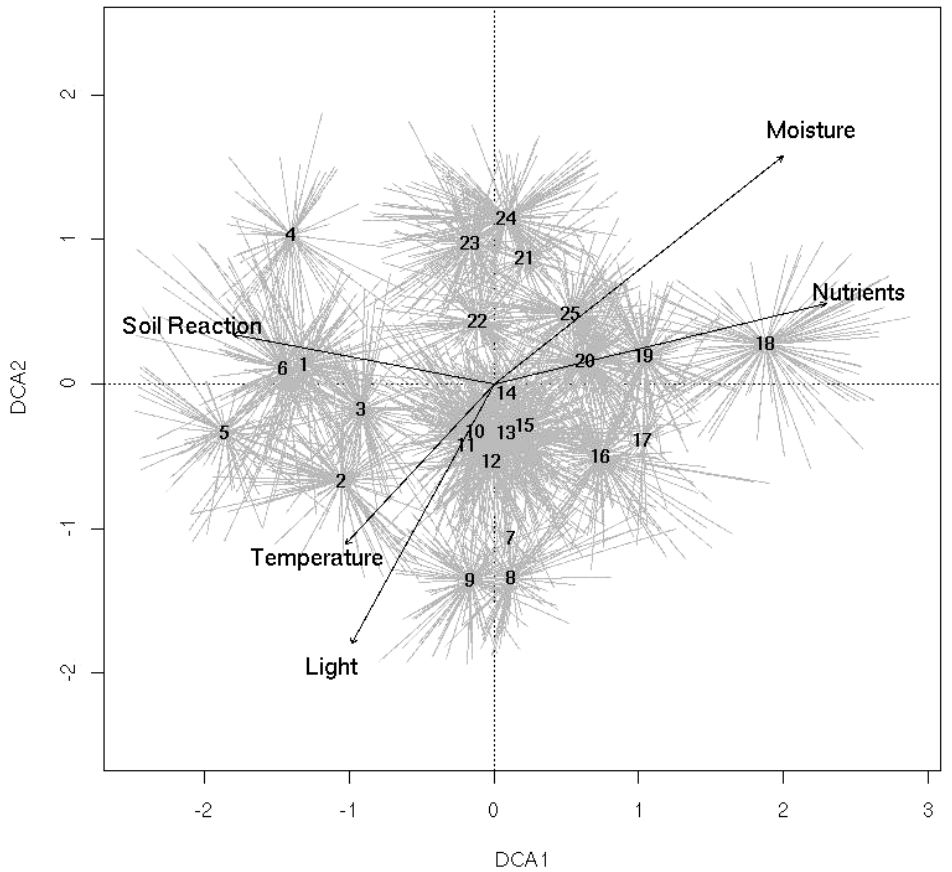


Fig. 3. – DCA ordination diagram with Borhidi indicator values plotted as supplementary variables. The variables significantly correlated with the ordination axes are shown. Axes are scaled in standard deviation units. Each 'spider' connects individual relevés with the average score for relevés belonging to the same cluster. Total inertia is 30.931, the first two eigenvalues are 0.435 and 0.350. Clusters 1–6 represent the *Bromo pannonici-Festucion pallentis* alliance, clusters 7–14, 17 and 19–25 the *Festucion valesiacae* alliance, clusters 15 and 16 the *Koelerio-Phleion phleoidis* alliance and cluster 18 the *Cynosurion cristati* alliance.

17–25) comprises relevés of closed dry grasslands on rather deep and nutrient-rich soil with better water-holding capacity. Fig. 4 shows a comparison of clusters using indicator values (Borhidi 1993).

The alliances *Bromo pannonici-Festucion pallentis* and *Festucion valesiacae* are clearly separated at the highest classification level (Fig. 2). The *Koelerio-Phleion phleoidis* alliance is nested in the group of clusters which otherwise represent the *Festucion valesiacae* alliance. At the lowest classification level, 27 clusters were distinguished. Two clusters (marked X and Y in Fig. 2) represent two local vegetation types, with nearly all the relevés from a small area and made by the same person (X: 29 relevés, Szarvaskő-Várhegy, HU, Szerdahelyi 1986; Y: 39 relevés, Marchfeld, AT, Schuster 1974). For this reason, these two clusters were excluded from the analysis and the interpretation based on only 25 clusters.

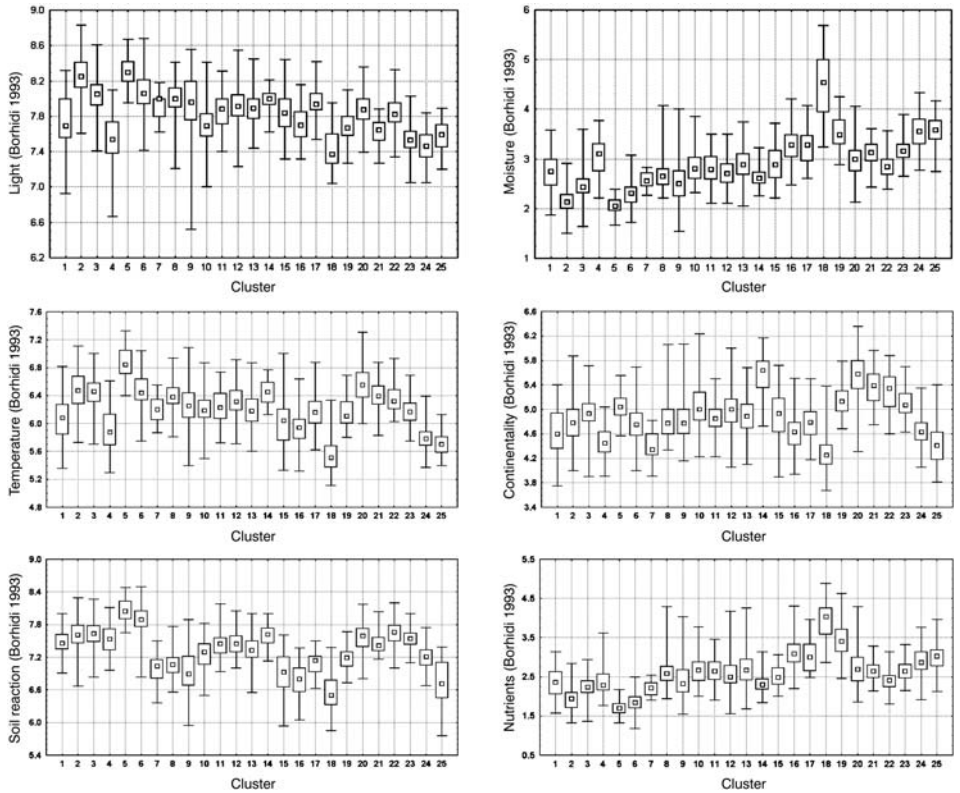
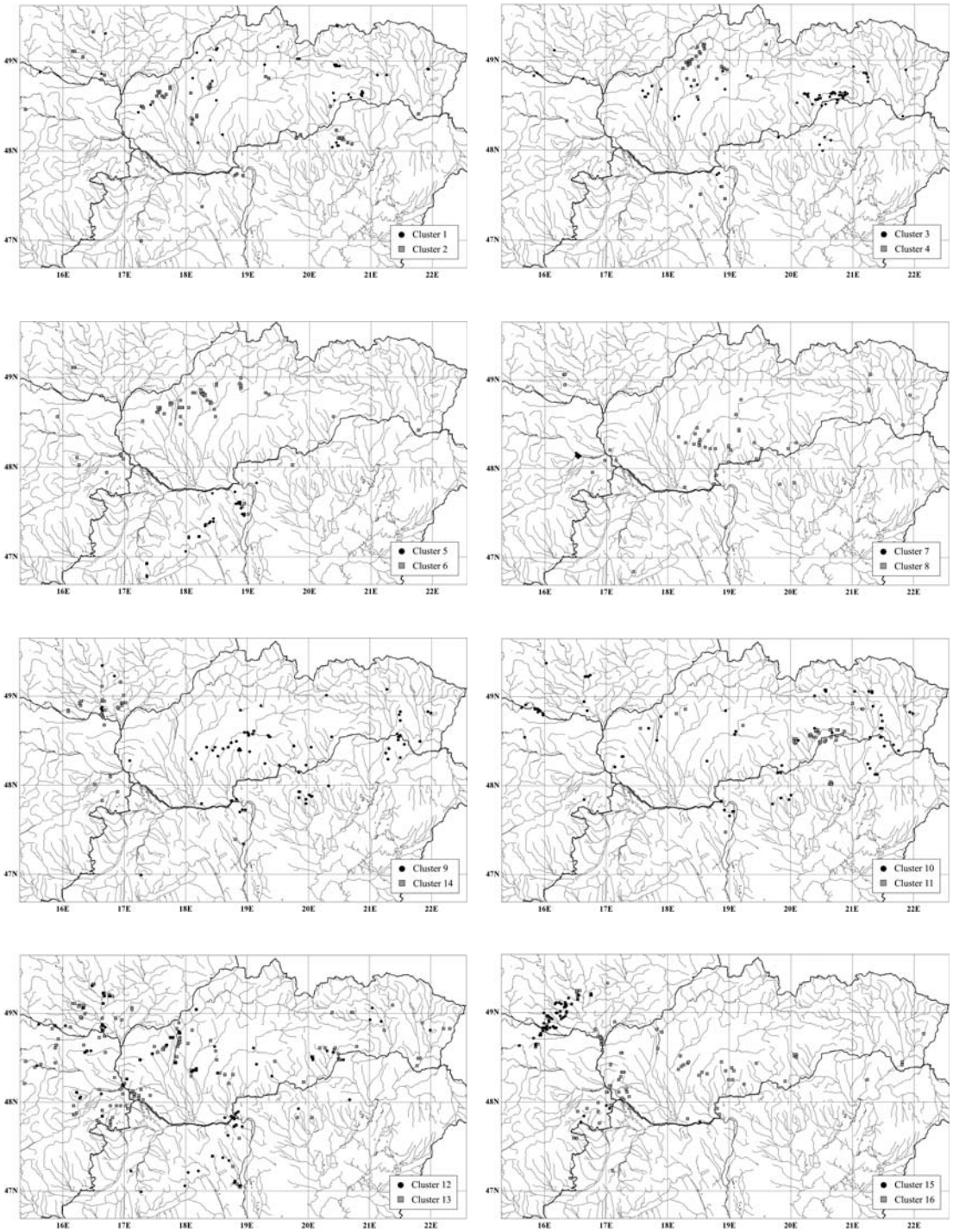


Fig. 4. – A comparison of clusters using Borhidi indicator values. Boxes and whiskers include 25–75% and 5–95% of the observed values, respectively, and squares inside the boxes are medians.

The majority of clusters can be assigned to one or more previously described associations (Table 1). For each cluster its syntaxonomical affiliation, synonyms (including only the names frequently used in the study area), list of diagnostic, constant and dominant species, short description and distribution map are presented (Fig. 5). The vegetation of some clusters is documented by photographs (Figs 6–8) and relevés that were published in Dúbravková et al. (2010). If a cluster includes more than one association, the association names are numbered based on decreasing proportion of their relevés in the cluster. If relevés of an association occur in more than one cluster, the synonyms of this association are only listed once, namely in the description of the cluster that includes the major part of this association. The synoptic table is divided into two parts: Table 2 includes clusters 1–6 (*Bromo pannonici-Festucion pallentis*) and Table 3 clusters 7–25 (*Festucion valesiacae*, *Koelerio-Phleion phleoidis* and one association of *Cynosurion cristati*).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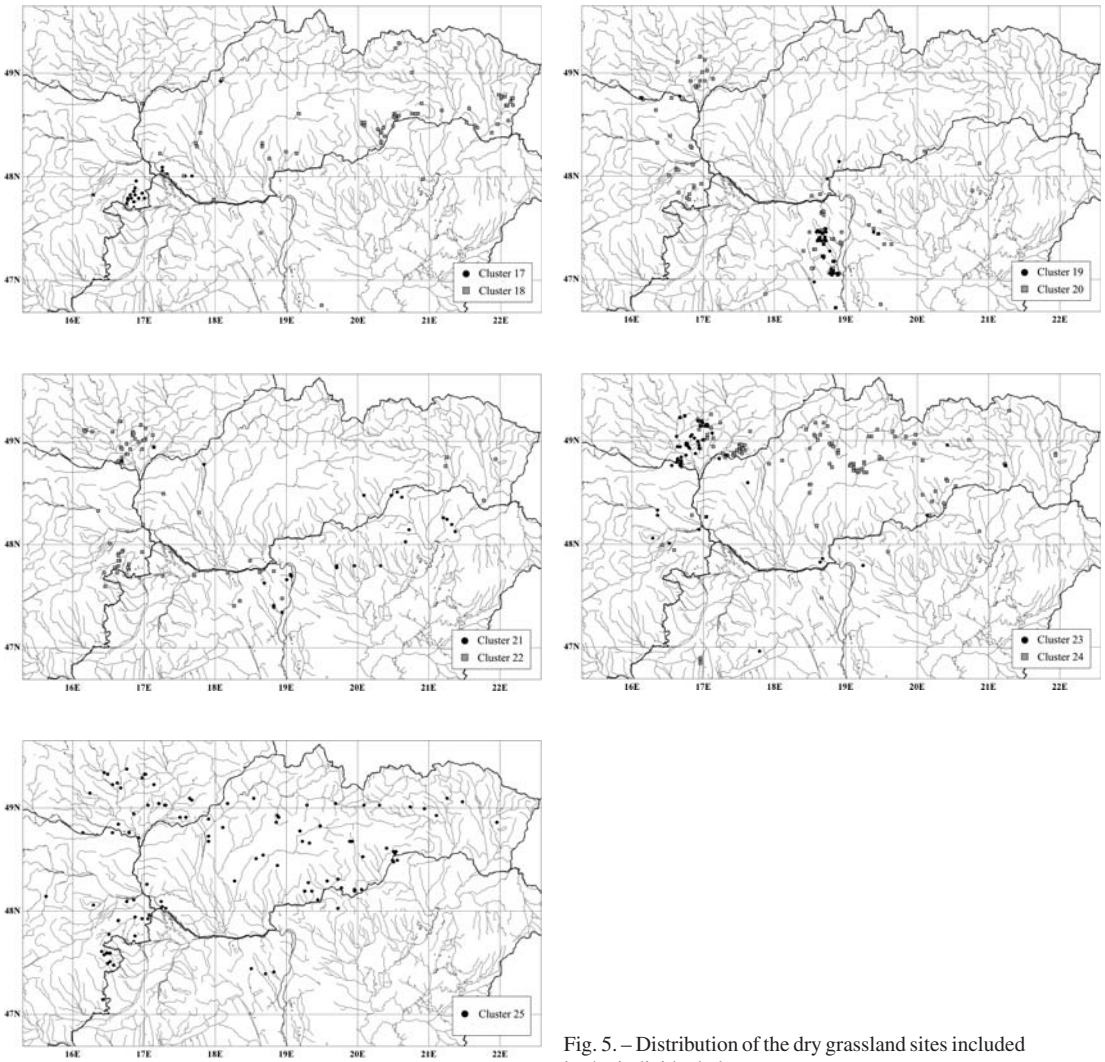

Fig. 5. – Distribution of the dry grassland sites included in the individual clusters.

Description of alliances

Bromo pannonici-Festucion pallentis Zólyomi 1966 (Clusters 1–6)

Syn.: *Seslerio-Festucion glaucae* Klika 1931 p. p. (Art. 35, 43), *Seslerio-Festucion pallentis* Klika 1931 corr. Zólyomi 1966 p. p. (Art. 35)

Number of relevés: 627

Diagnostic species: *Acinos alpinus*, *A. arvensis*, *Allium flavum*, *A. ochroleucum*, *A. senescens* subsp. *montanum*, ***Alyssum montanum***, ***Anthericum ramosum***, *Anthyllis vulneraria*, *Asperula tinctoria*, ***Asplenium ruta-muraria***, *A. trichomanes*, *Astragalus vesicarius*, *Biscutella laevigata*, ***Campanula sibirica***, *Cardaminopsis arenosa* agg., ***Carex humilis***, *Chamaecytisus hirsutus*, *Cyanus triumfettii*, *Dianthus plumarius* subsp. *regis-stephani*, *D. praecox*, *Draba lasiocarpa*, *Erysimum odoratum, E. witmannii*, ***Festuca pallens***, ***Fumana***

Table 1. – Correspondence between the traditional syntaxa and clusters distinguished by modified TWINSPAN. Clusters which could not be assigned to a certain association and clusters with successionally advanced or transitional vegetation are not listed here but described in the main text.

Associations and high-level syntaxa	Major occurrence in cluster	Minor occurrence in cluster
Festuco-Brometea Br.-Bl. et Tüxen ex Soó 1947		
Stipo pulcherrimae-Festucetalia pallentis Pop 1968		
Bromo pannonici-Festucion pallentis Zólyomi 1966		
Poo badensis-Caricetum humilis (Dostál 1933) Soó ex Michálková in Janišová et al. 2007	3	
Campanulo divergentiformis-Festucetum pallentis Zólyomi (1936) 1966	3	
Orthantho luteae-Caricetum humilis Kliment et Bernátová 2000	4	
Seselio leucospermi-Festucetum pallentis Zólyomi 1936 corr. 1966 nom. invers. propos.	5	
Stipo-Caricetum humilis Soó 1930	5	
Festuco pallentis-Caricetum humilis Sillinger 1930 corr. Gutermann et Mucina 1993	6	
Poo badensis-Festucetum pallentis Klika 1931 corr. Zólyomi 1966 nom. invers. propos.	6	
Festuco pallentis-Brometum pannonici (Zólyomi 1958) Soó 1959 corr. 1964	6	4
Festucetalia valesiacae Br.-Bl. et Tüxen ex Br.-Bl. 1949		
Festucion valesiacae Klika 1931		
Teucrio botryos-Andropogonetum ischaemi Sauberer et Wagner in Sauberer 1942	7	
Inulo oculi-christi-Festucetum pseudodalmaticae Májovský et Jurko 1956	8	
Festucetum pseudodalmaticae Mikyška 1933	9	10
Alysso heterophylli-Festucetum valesiacae (Dostál 1933) Kliment in Kliment et al. 2000	11	
Festuco valesiacae-Stipetum capillatae Sillinger 1930	12, 13	14, 20
Astragalo exscapi-Crambetum tatariae Klika 1939 nom. invers. propos.	14	
Koelerio macranthae-Stipetum joannis Kolbek 1978	14	12
Avenastro besseri-Stipetum joannis Klika 1951 corr. Kolbek in Moravec et al. 1983	14	
Festuco pseudovinae-Caricetum stenophyllae (Bojko 1934) Wendelberger 1954	17	16
Salvio nemorosae-Festucetum rupicolae Zólyomi ex Soó 1959	20	
Stipetum tirsae Meusel 1938	21	10
Astragalo austriaci-Festucetum sulcatae Soó 1957	22	
Festuco rupicolae-Caricetum humilis Klika 1939	25	
Koelerio-Phleion phleoidis Korneck 1974		
Avenulo pratensis-Festucetum valesiacae Vicherek et al. in Chytrý et al. 1997	15	
Potentillo heptaphyllae-Festucetum rupicolae (Klika 1951) Toman 1970	16	
Molinio-Arrhenatheretea Tüxen 1937		
Arrhenatheretalia elatioris Tüxen 1931		
Cynosurion cristati Tüxen 1947 nom. cons. propos.		
Alopecuro pratensis-Festucetum pseudovinae Juhász-Nagy 1957	18	

procumbens, *Genista pilosa*, ***Globularia punctata***, ***Helianthemum nummularium* agg.**, *Hieracium bupleuroides*, *Hippocrepis comosa*, *Hornungia petraea*, *Inula ensifolia*, ***Jovibarba globifera***, *Jurinea mollis*, *Lactuca perennis*, ***Leontodon incanus***, ***Linum tenuifolium***, ***Melica ciliata***, *Minuartia langii*, *M. rubra*, *M. setacea*, *M. verna* agg., *Onosma visianii*, *Paronychia cephalotes*, *Phyteuma orbiculare*, ***Poa badensis***, *Polygonatum odoratum*, *Pulsatilla grandis*, *P. slavica*, *P. subslavica*, ***Rhodax canus***, *Sanguisorba minor*, *Saxifraga paniculata*, ***Scorzonera austriaca***, ***Sedum album***, *Seseli leucospermum*, ***S. osseum***, ***Sesleria albicans***, *Silene otites* agg., *Stachys recta*, *Stipa eriocaulis*, *S. pulcherrima*, *Teucrium chamaedrys*, ***T. montanum***, ***Thymus praecox***, *Tithymalus seguierianus*, ***Vincetoxicum hirundinaria***

Constant species: *Anthericum ramosum*, *Asperula cynanchica*, ***Carex humilis***, ***Festuca pallens***, *Helianthemum nummularium* agg., *Jovibarba globifera*, *Potentilla verna* agg., *Sanguisorba minor*, *Seseli osseum*, *Teucrium chamaedrys*, ***T. montanum***, *Thymus praecox*, ***Tithymalus cyparissias***

Dominant species: ***Carex humilis***, *Festuca pallens*, *Potentilla verna* agg.

Fig. 6. – Examples of vegetation stands belonging to particular clusters. **Cluster 3 –** *Poo badensis-Caricetum humilis* in a karst rocky field in the Kečovské škrapy National Nature Reserve, Slovenský kras Mts, SK (photo: D. Dúbravková 2005). **4** – *Orthantho luteae-Caricetum humilis* dominated by *Carex humilis* and *Bromus monocladus* on a gravel terrace of the Turiec river in Moškovec, Turčianska kotlina Basin, SK (D. Dúbravková 2006). **5** – *Seselio leucospermi-Festucetum pallentis* at Szénások Mt., Pilis Mts, HU. Some endemic and sub-mediterranean species occur among ring tussocks of *Carex humilis*, e.g. *Paronychia cephalotes* (inset) (D. Dúbravková 2006). **6** – *Festuco pallentis-Caricetum humilis* with *Carex humilis*, *Allium flavum* and *Teucrium montanum* in the Hainburger Berge Hills, AT (D. Dúbravková 2007). **7** – *Teucrio botryos-Andropogonetum ischaemi* with scattered bushes on fluvial gravel sediments at Untere Lobau, Vienna, AT (D. Rotter 1999). **8** – Stands of *Inulo oculi-christi-Festucetum pseudodalmaticae* usually dry out in early summer, such as in Medovarce, Krupinská planina Plateau, SK. The only species that remain green are *Festuca pseudodalmatica* and *Cardus collinus* (M. Janišová 2005).

Fig. 7. – Examples of vegetation stands belonging to particular clusters. **Cluster 9** – Open dry grassland of *Festucetum pseudodalmaticae* in the Börzsöny Mts, HU (photo: D. Dúbravková 2006). **11** – *Alysso heterophylli-Festucetum valesiacae* with *Festuca valesiaca*, *Koeleria macrantha*, *Sedum acre* and *Thymus pannonicus* in the Turniansky hradný vrch National Nature Reserve, Slovenský kras Mts, SK (R. Šuvada 2005). **12 and 13** – Last-year leaf blades of *Stipa capillata* in a stand of *Festuco valesiacae-Stipetum capillatae* on Kalvárie Hill near Zaječí, southern Moravia, CZ (M. Chytrý 2005). **14** – *Astragalo exscapi-Crambetum tatariae* on disturbed loess soil in Pouzdřany, southern Moravia, CZ (M. Chytrý 2005). **15** – Acidophilous dry grassland of *Avenulo pratensis-Festucetum valesiacae* on Kamenný vrch hill near Brno, CZ (M. Chytrý 2005). **16** – *Steris viscaria* and *Dianthus pontederae* blooming in a stand of *Potentillo heptaphyllae-Festucetum rupicolae* in the Lány meadows near Lanžhot, southern Moravia, CZ (M. Chytrý 2005).

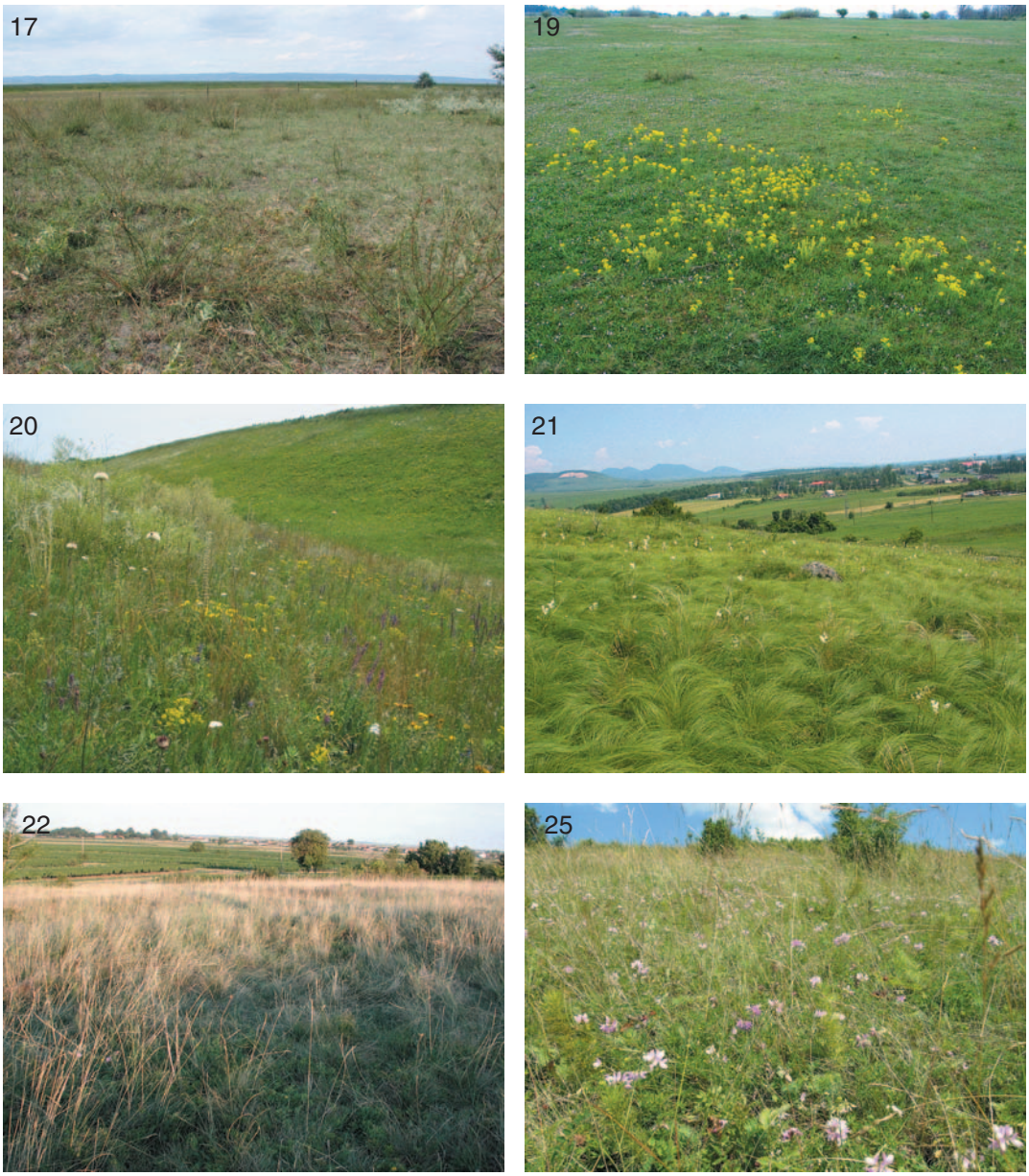

Fig. 8. – Examples of vegetation stands belonging to particular clusters. **Cluster 17** – *Festuco pseudovinae-Caricetum stenophyllae* near Seedamm in Illmitz, Burgenland, AT (K.-P. Zulka 2001). **19** – *Tithymalus glareosus*, *Festuca valesiaca* and *Linum tenuifolium* in a former arable field and current pasture in Vértesboglár, HU (photo: E. Illyés 2006). **20** – Stands of *Salvio nemorosae-Festucetum rupicolae* with numerous colourful herbaceous plants such as *Salvia nemorosa*, *Tithymalus glareosus*, *Crambe tataria* and *Jurinea mollis* near Belsőbáránd, HU (J. Bölöni 2008). **21** – Closed grassland of *Stipetum tirsae* with *Stipa tirsa* and *Filipendula vulgaris* on Mandulás Mt. near Sárospatak, HU (E. Illyés 2005). **22** – *Astragalo austriaci-Festucetum sulcatae* near Rosalia-Kapelle in Oggau, Burgenland, AT (K.-P. Zulka 2001). **25** – *Festuco rupicolae-Caricetum humilis* with *Festuca rupicola*, *Securigera varia*, *Fragaria viridis* and *Adonis vernalis* in a semi-dry extensive pasture in Hrušov, Drienčanský kras Mts, SK (K. Ujházy 2006).

Table 2. – A shortened synoptic table of the *Bromo pannonici-Festucion pallentis* alliance (clusters 1–6) with percentage constancy. Shaded species are ranked by decreasing fidelity (decreasing values of the phi coefficient of association between the species and the cluster); dark shading: $\Phi \geq 0.30$, light shading: $0.15 < \Phi < 0.30$. Diagnostic species with constancy < 9% are not shown.

Cluster no.	1	2	3	4	5	6
No. of relevés	96	107	152	64	64	144
Cluster 1: Grassland vegetation of cool and humid cliffs and rocky slopes with montane species						
Asplenium ruta-muraria	54	17	17	12	9	2
Cyanus triumfettii	41	3	9	8	.	6
Polygonatum odoratum	44	2	14	14	3	5
Saxifraga paniculata	21	2	3	.	.	.
Galium mollugo agg.	30	6	7	2	.	.
Securigera varia	43	5	16	5	.	1
Campanula rapunculoides	20	.	1	5	.	.
Spiraea media	16	.	2	.	.	.
Hieracium bupleuroides	20	.	1	8	.	.
Aster alpinus	11	.	1	.	.	.
Hylotelephium maximum agg.	21	3	6	.	.	.
Silene nemoralis	10	.	.	.	.	.
Hieracium murorum s.l.	11	.	.	2	.	1
Cotoneaster integerrimus	11	.	1	2	.	.
Aconitum anthora	9	.	1	.	.	.
Dianthus praecox subsp. *praecox*	10	.	1	.	.	1
Lembotropis nigricans	16	.	1	8	.	.
Colymbada scabiosa	32	2	6	22	.	2
Origanum vulgare	24	.	14	12	.	.
Allium senescens subsp. *montanum*	39	20	5	23	17	17
Acinos arvensis	43	29	27	3	20	8
Tithymalus epithymoides	14	.	4	11	.	.
Chamaecytisus hirsutus	15	2	11	2	.	3
Cardaminopsis arenosa agg.	15	4	3	12	2	3
Cluster 2: Various rocky grasslands with *Festuca pallens*						
Artemisia austriaca	.	9	1	.	.	.
Hesiodia montana	.	9	1	.	2	1
Cluster 3: Rocky grasslands with *Festuca pallens* and *Carex humilis* at the north-eastern periphery of the Pannonian Basin						
Potentilla verna agg.	41	59	86	5	3	38
Linaria pallidiflora	1	.	16	.	.	.
Campanula sibirica	32	21	49	2	14	17
Verbascum lychnitis	12	4	24	.	.	1
Iris pumila	2	5	22	.	5	1
Onosma tornensis	.	.	9	.	.	.
Cleistogenes serotina	.	4	15	.	2	1
Stipa joannis	5	4	20	5	.	6
Poa badensis	4	30	38	2	25	24
Echium vulgare	11	12	30	12	2	3
Salvia pratensis	28	3	43	45	3	1
Taraxacum sect. *Erythrosperma*	4	4	17	.	6	5

Cluster no.	1	2	3	4	5	6
No. of relevés	96	107	152	64	64	144
Galium glaucum	30	5	36	19	11	2
Minuartia rubra	.	7	11	.	3	5
Cluster 4: Submontane grasslands with *Carex humilis* and *Bromus pannonicus* s.l.						
Potentilla heptaphylla	7	2	2	69	.	23
Acinos alpinus	10	1	2	53	.	6
Bromus pannonicus s.l.	2	.	1	38	3	7
Platanthera bifolia	.	.	.	22	.	.
Carduus glaucinus	5	.	.	27	.	1
Cirsium pannonicum	.	.	.	22	.	.
Leucanthemum vulgare agg.	11	.	1	34	.	3
Hippocrepis comosa	11	1	17	52	14	14
Carlina acaulis	3	2	1	31	.	3
Ophrys insectifera	.	.	.	19	.	1
Phyteuma orbiculare	5	.	.	33	5	11
Polygala amara agg.	.	.	1	20	.	3
Tephroseris integrifolia	.	.	.	16	.	.
Brachypodium pinnatum	10	.	3	34	.	1
Viola hirta	18	3	9	38	2	1
Pulsatilla subslavica	9	.	1	22	.	.
Allium ochroleucum	14	.	3	25	.	.
Galium pumilum agg.	12	2	.	27	.	5
Gymnadenia conopsea	1	.	.	14	.	1
Linum catharticum	8	.	4	27	.	2
Asperula tinctoria	18	1	4	31	2	7
Senecio umbrosus	.	.	.	11	.	.
Anthericum ramosum	52	25	51	86	67	47
Hieracium bifidum	3	.	.	12	.	.
Cotoneaster tomentosus	4	.	.	12	.	1
Inula salicina	1	.	.	11	.	.
Coronilla vaginalis	2	.	1	12	.	2
Anthyllis vulneraria	23	12	34	59	47	38
Thesium alpinum	4	.	.	9	.	.
Dorycnium pentaphyllum agg.	.	7	14	44	38	31
Salvia verticillata	17	.	5	20	.	3
Euphrasia rostkoviana agg.	2	.	5	9	.	.
Campanula rotundifolia agg.	8	12	6	25	.	19
Minuartia langii	8	4	1	14	.	6
Biscutella laevigata	11	1	3	20	11	15
Thalictrum minus	5	2	11	22	16	8
Cluster 5: Rocky grasslands on dolomite in the Dunántúli-középhegység Mts (Hungarian Transdanubian Range)						
Seseli leucospermum	.	.	.	.	66	6
Tithymalus seguierianus	.	10	1	2	73	15
Stipa eriocaulis	.	3	1	2	58	6
Minuartia setacea	5	20	2	.	64	4
Paronychia cephalotes	.	.	.	.	36	1
Dianthus plumarius subsp. *regis-stephani*	.	.	.	.	36	4

Cluster no.	1	2	3	4	5	6
No. of relevés	96	107	152	64	64	144
Cerastium brachypetalum agg.	.	.	1	.	38	3
Hornungia petraea	.	1	.	.	41	13
Chrysopogon gryllus	.	2	1	.	33	1
Aethionema saxatile	.	.	.	.	23	.
Allium moschatum	.	.	.	.	22	2
Carex liparocarpos	.	.	1	.	23	2
Holosteum umbellatum	1	1	1	.	20	3
Silene otites agg.	21	27	18	.	56	27
Melampyrum nemorosum	4	.	3	.	19	1
Artemisia alba	.	1	.	.	12	1
Poa bulbosa	1	7	.	.	25	3
Orthantha lutea	.	.	1	2	20	8
Alyssum tortuosum s.l.	.	.	1	.	11	.
Saxifraga tridactylites	3	8	4	.	23	8
Minuartia verna agg.	.	5	3	.	17	9
Seseli hippomarathrum	.	4	.	2	22	15
Erophila verna agg.	1	9	.	.	19	5
Sanguisorba minor	26	50	35	61	75	65
Scabiosa canescens	.	3	1	5	20	15
Draba lasiocarpa	5	10	1	3	19	15
Cluster 6: Calcareous rocky grasslands with *Carex humilis* and *Festuca pallens* at the western periphery of the Western Carpathians						
Jurinea mollis	1	1	14	3	16	26
Alyssum montanum	1	21	31	3	30	40
Viola rupestris	.	.	.	2	5	10
Dianthus praecox subsp. *lumnitzeri*	2	8	1	.	2	11
Diagnostic species common to two or more clusters						
Seseli osseum	85	53	66	39	12	47
Stachys recta	57	18	54	8	9	3
Vincetoxicum hirundinaria	77	3	31	67	16	16
Inula ensifolia	57	8	30	84	5	13
Sesleria albicans	31	6	1	66	.	11
Bupleurum falcatum	30	1	13	41	.	8
Geranium sanguineum	32	6	12	31	.	.
Erysimum witmannii	27	1	2	25	.	1
Pulsatilla slavica	21	.	5	19	.	.
Sedum album	50	80	12	6	20	18
Asplenium trichomanes	15	12	1	2	.	.
Jovibarba globifera	69	63	55	31	42	41
Festuca pallens	82	86	76	34	66	74
Veronica austriaca	21	1	18	2	5	3
Lactuca perennis	20	4	26	.	2	.
Erysimum odoratum	28	24	26	2	6	3
Melica ciliata	34	52	55	16	12	16
Allium flavum	17	47	52	3	20	15
Arenaria serpyllifolia agg.	21	40	17	2	44	14
Astragalus vesicarius	.	.	9	.	9	.

Cluster no.	1	2	3	4	5	6
No. of relevés	96	107	152	64	64	144
Teucrium chamaedrys	57	33	77	78	6	33
Tithymalus cyparissias	70	58	80	80	17	53
Helianthemum nummularium agg.	48	30	62	62	34	42
Genista pilosa	6	9	16	75	14	45
Leontodon incanus	15	25	5	69	5	46
Carex humilis	54	28	77	97	92	87
Globularia punctata	6	3	4	50	73	55
Teucrium montanum	35	27	68	78	89	75
Linum tenuifolium	2	2	18	41	44	47
Rhodax canus	4	14	29	8	73	65
Fumana procumbens	3	10	4	19	89	35
Scorzonera austriaca	2	7	7	11	78	33
Thymus praecox	18	50	31	45	75	77
Other species with constancy ≥ 10% in at least one cluster						
Stipa pulcherrima	14	12	18	11	17	23
Pulsatilla grandis	28	8	26	8	12	17
Asperula cynanchica	54	50	63	62	47	55
Hypericum perforatum	18	10	32	5	3	8
Scabiosa ochroleuca	32	24	45	23	5	25
Crinitina linosyris	4	1	7	2	14	11
Thesium linophyllon	8	3	7	11	27	17
Pilosella bauhinii	2	12	24	25	9	26
Sedum sexangulare	6	31	26	6	2	11
Bothriochloa ischaemum	1	15	39	3	16	16
Festuca rupicola	6	3	12	8	3	14
Verbascum chaixii subsp. *austriacum*	7	2	14	8	2	.
Achillea millefolium s.l.	12	4	29	3	.	1
Pimpinella saxifraga agg.	11	6	8	48	.	10
Acosta rhenana	4	23	37	2	.	11
Pilosella officinarum	5	10	15	16	.	17
Dianthus carthusianorum	31	3	11	23	.	4
Sedum acre	23	16	18	6	.	8
Festuca valesiaca	1	24	22	2	.	3
Artemisia campestris	19	15	26	.	.	3
Thymus pannonicus	9	9	27	.	6	1
Stipa capillata	4	18	26	.	9	10
Linaria genistifolia	4	15	12	.	3	5
Koeleria macrantha s.l.	9	22	51	.	34	19
Pseudolysimachion spicatum agg.	27	6	34	.	12	15
Eryngium campestre	.	10	28	.	2	3
Arabis hirsuta agg.	15	1	11	5	.	6
Medicago falcata	6	5	24	9	.	7
Plantago lanceolata	2	3	12	8	.	1

Table 3. – A shortened synoptic table of the *Festucion valesiacae*, *Koelerio-Phleion phleoidis* and *Cynosurion cristati* alliances (clusters 7–25) with percentage constancy. Shaded species are ranked by decreasing fidelity (phi coefficient of association between the species and the cluster). Dark shading: $\Phi \geq 0.30$, light shading: $0.15 < \Phi < 0.30$. Diagnostic species with constancy < 9% are not shown.

Cluster no.	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
No. of relevés	12	81	115	119	69	148	266	58	88	135	31	91	101	192	46	104	121	152	130
Cluster 7: Open grasslands on alluvial soils along the Danube river																			
Teucrium botrys	58	1	.	.	3	1	2	.	.	.	.	.	.	.	.	.	.	.	.
Apera interrupta	42	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Saxifraga tridactylites	67	5	3	.	3	11	8	2	2	3	13	.	.	.	.	2	.	.	.
Erophila verna agg.	75	12	10	4	.	6	11	2	15	17	29	13	.	.	2	2	.	1	.
Cerastium pumilum agg.	67	14	3	4	4	18	12	10	10	17	26	1	.	2	.	10	2	1	3
Bothriochloa ischaemum	100	59	17	16	39	42	35	59	18	10	16	5	50	42	11	61	10	18	26
Sedum sexangulare	58	37	26	13	43	43	42	.	42	23	19	7	.	1	2	2	1	9	15
Cluster 8: Semi-closed grasslands on volcanic bedrocks in the Inner Western Carpathians with *Festuca pseudodalmatica* and sub-mediterranean species																			
Valerianella dentata	.	27	.	1	3	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Logfia arvensis	.	30	5	1	.	.	1	.	1	1	.	.	.	1	.	.	.	.	1
Cruciata pedemontana	17	51	7	1	3	8	3	.	.	14	10	1	1	.	.	1	.	.	1
Cleistogenes serotina	.	32	5	1	10	6	1	.	.	.	.	.	.	1	.	.	.	.	.
Cerastium brachypetalum agg.	.	42	11	6	4	7	1	2	1	11	.	.	.	6	2	.	2	.	2
Orlaya grandiflora	.	19	3	.	.	5	1	.	.	1	.	.	.	.	.	.	.	.	.
Viola kitaibeliana	.	21	2	2	3	4	1	.	.	1	.	.	.	2	.	.	.	.	.
Galium aparine agg.	.	19	1	3	.	3	2	.	.	1	.	.	.	3	.	.	.	.	.
Leopoldia comosa	.	36	4	4	1	9	6	2	.	6	6	3	4	9	4	2	2	5	5
Erysimum crepidifolium	.	10	1	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.
Petrorhagia prolifera	.	28	9	5	10	11	5	.	.	14	.	3	.	.	.	.	.	.	3
Viola tricolor agg.	.	16	8	3	.	1	1	.	.	1	.	1	.	.	.	.	1	.	.
Inula oculus-christi	.	27	1	9	6	12	4	17	2	.	6	.	.	13	7	1	8	.	1
Melica transsilvanica	.	22	17	16	1	11	9	.	5	4	.	.	7	3	13	.	1	.	4
Cluster 9: *Festuca pseudodalmatica* open rocky grasslands on volcanic bedrock																			
Minuartia hirsuta	.	.	18	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Asplenium septentrionale	.	1	23	4	.	1	.	.	.	1	.	.	.	.	.	.	.	.	.
Cardaminopsis arenosa agg.	.	2	18	4	.	1	.	.	.	.	.	.	.	1	.	.	.	3	2
Jovibarba globifera	.	.	36	3	28	11	6	.	2	.	.	.	.	.	.	.	.	5	4
Seseli osseum	.	40	63	45	33	40	29	34	48	18	.	2	.	1	28	11	8	7	6
Cluster 10: Dry grasslands with thermophilous forest species																			
Verbascum chaixii subsp. *austriacum*	.	23	24	55	9	9	6	5	5	13	.	1	.	2	7	4	2	7	3
Stachys recta	.	32	34	68	43	51	20	38	1	7	.	1	12	31	35	29	43	11	10
Potentilla recta	.	2	8	18	6	2	1	.	.	3	.	1	.	1	7	.	2	.	2
Cerasus fruticosa	.	1	1	19	.	3	2	2	5	1	.	.	.	3	9	3	9	1	.
Origanum vulgare	.	1	8	27	12	3	2	.	.	1	.	1	2	1	20	.	11	12	5
Polygonatum odoratum	.	.	2	16	7	6	2	.	1	1	.	.	.	.	4	.	7	5	.
Cluster 11: Steppe grasslands with *Festuca valesiaca* s.l. at the north-eastern periphery of the Pannonian Basin																			
Achillea nobilis	.	30	24	23	68	5	6	.	.	9	10	10	.	1	2	.	2	2	12
Teucrium montanum	.	1	.	3	46	5	12	3	.	.	.	1	2	2	2	16	5	15	9
Asplenium ruta-muraria	.	.	.	1	19	3	1	.	.	.	.	.	.	.	.	.	.	.	.

Cluster no.	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
No. of relevés	12	81	115	119	69	148	266	58	88	135	31	91	101	192	46	104	121	152	130
Ajuga genevensis	.	4	6	3	22	1	1	.	.	4	6	4	.	.	2	.	1	2	3
Fragaria moschata	.	7	3	2	16	1	1	.	.	.	.	2	.	.	.	1	1	9	1
Linaria pallidiflora	.	.	4	8	13	2	.	.	.	.	.	.	.	.	.	.	.	.	.
Ranunculus bulbosus	.	.	.	1	17	1	3	.	2	1	3	3	.	.	.	.	5	7	10
Echium vulgare	8	41	22	22	51	31	38	22	27	17	6	7	5	2	2	8	7	16	19
Stachys germanica	.	.	.	2	10	1	1	.	.	2	.	2	1	.	.	.	.	.	5
Filago vulgaris	8	1	2	2	14	.	.	.	.	.	3	2	.	.	4	2	2	1	5
Convolvulus arvensis	.	17	4	1	32	21	18	2	.	13	19	22	11	7	.	.	2	.	11
Prunella laciniata	.	.	.	1	16	2	3	.	.	4	3	8	1	.	.	.	1	13	14
Cyanus triumfettii	.	1	3	14	19	8	4	3	3	1	.	2	.	.	.	1	12	8	2
Verbascum lychnitis	.	1	2	6	19	15	8	.	2	8	3	1	.	1	7	1	7	1	4
Clusters 12: Basal community of Central European dry grasslands dominated by *Festuca valesiaca* s.l.																			
Alyssum alyssoides	.	23	17	16	14	37	16	10	1	5	3	.	.	6	.	4	2	1	3
Sedum album	.	9	14	3	4	28	14	3	.	.	.	.	.	.	.	1	1	1	1
Minuartia rubra	.	.	1	.	1	11	8	.	.	.	.	.	.	1	.	.	.	.	.
Cluster 14: Open grasslands on loess with *Festuca valesiaca* and relict species of continental steppes																			
Astragalus exscapus	.	.	.	1	.	.	1	33	1	.	.	.	.	3	.	3	.	.	.
Crambe tataria	.	.	.	1	.	.	1	31	.	.	.	.	.	2	.	3	6	.	1
Iris pumila	.	5	9	9	10	18	9	40	6	1	10	.	.	11	4	12	12	.	.
Minuartia setacea	.	1	7	.	1	3	2	19	1	1	.	.	.	.	.	1	.	.	.
Corothamnus procumbens	.	.	.	3	1	1	2	19	6	.	.	.	.	.	9	2	10	1	1
Senecio jacobaea	.	1	.	2	16	5	14	36	22	8	10	.	19	12	2	11	13	8	8
Oxytropis pilosa	.	.	.	2	.	.	1	12	1	.	.	.	1	2	.	8	5	.	.
Koeleria macrantha s.l.	8	54	38	60	78	69	69	93	72	55	16	20	50	62	63	56	47	45	60
Verbascum phoeniceum	.	14	2	18	3	7	4	29	20	14	10	2	4	20	17	3	.	1	2
Cluster 15: Dry grasslands with *Festuca valesiaca* on acidic soils																			
Agrostis vinealis	.	.	.	2	.	.	1	.	66	12	.	1	.	.	.	.	.	7	15
Festuca ovina agg.	.	.	1	6	.	.	2	.	28	2	.	.	.	1	.	.	.	1	8
Thymus praecox	.	19	16	7	6	20	30	28	76	9	23	7	1	4	.	23	9	16	7
Genista pilosa	.	.	6	.	4	1	3	2	47	7	.	.	.	.	2	13	2	22	14
Helichrysum arenarium	.	.	.	.	.	1	2	.	16	1	3	.	.	.	.	.	.	.	.
Gagea bohemica	.	.	.	.	.	.	1	.	9	.	.	.	.	.	.	.	.	.	.
Sedum rupestre	.	2	.	3	.	1	1	.	11	1	.	.	.	.	.	.	.	.	.
Scleranthus perennis	.	1	.	2	.	.	1	.	10	4	.	.	.	.	.	.	.	.	2
Pulsatilla grandis	.	.	.	10	12	7	12	16	32	1	.	.	.	1	15	20	19	9	5
Cluster 16: Dry grasslands on base-poor substrata																			
Vicia lathyroides	.	6	1	1	3	3	1	.	.	19	.	1	.	2	.	.	.	.	2
Carex praecox agg.	.	5	2	5	.	3	3	.	9	27	.	13	.	2	2	.	.	2	2
Valerianella locusta	.	5	3	1	.	4	1	.	.	12	.	.	.	1	2	.	.	.	1
Ornithogalum umbellatum agg.	.	4	.	2	1	3	6	.	1	15	.	3	1	1	.	3	2	2	2
Peucedanum oreoselinum	.	.	.	1	.	.	1	7	5	14	.	1	.	1	.	9	2	1	6
Arabidopsis thaliana	.	6	9	4	1	6	5	9	2	17	.	2	.	4	.	2	.	1	2
Cluster 17: Dry grasslands with *Festuca pseudovina* on sandy soils																			
Carex stenophylla	.	1	.	1	.	2	3	.	.	4	39	.	.	1	.	.	.	.	.
Erodium moschatum	.	.	.	.	.	.	.	.	.	1	19	.	.	.	.	.	.	.	.

Cluster no.	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
No. of relevés	12	81	115	119	69	148	266	58	88	135	31	91	101	192	46	104	121	152	130
Taraxacum sect. *Erythrosperma*	.	.	.	.	.	.	1	.	.	1	16	.	.	.	.	.	.	1	.
Melilotus officinalis	.	1	1	3	3	2	4	.	1	1	29	.	3	2	.	.	5	3	2
Tithymalus seguierianus	.	2	.	.	1	1	5	9	2	.	32	.	1	9	.	12	1	.	2
Carduus nutans	.	1	.	1	12	3	8	.	1	1	26	3	.	4	.	.	2	.	3
Cerastium semidecandrum	8	7	8	3	.	7	13	.	7	19	35	3	2	3	4	2	.	.	.
Salvia austriaca	.	.	.	.	.	1	1	.	.	.	16	.	3	8	.	.	.	.	.
Erodium cicutarium	.	10	1	.	1	5	6	.	1	10	23	3	.	1	.	.	.	.	.
Poa bulbosa	.	22	17	6	.	9	20	2	25	19	39	7	.	2	.	.	.	.	2
Muscari neglectum	.	1	3	.	.	5	10	.	.	3	16	.	.	.	.	7	2	.	2
Viola rupestris	.	.	.	.	.	1	2	2	.	.	13	.	.	1	.	5	8	9	2
Cluster 18: Pastures with *Festuca pseudovina* and species of hay meadows																			
Alopecurus pratensis	.	.	.	.	.	1	.	.	.	3	.	46	.	.	4	.	.	.	1
Trifolium repens	.	.	1	.	6	1	4	.	.	7	10	63	1	1	.	.	.	2	15
Ranunculus acris agg.	.	.	.	.	.	.	.	.	.	1	3	41	.	.	.	.	.	.	4
Cerastium fontanum agg.	.	1	1	3	3	.	1	.	.	5	.	46	.	.	2	.	.	5	12
Potentilla reptans	.	.	.	.	.	1	1	.	.	2	.	31	.	.	.	.	.	.	3
Veronica serpyllifolia	.	.	1	.	.	.	.	.	.	.	.	24	.	.	.	.	.	.	.
Lychnis flos-cuculi	.	.	.	.	.	.	.	.	.	.	.	19	.	.	.	.	.	.	.
Stellaria graminea	.	1	.	.	.	.	.	.	.	1	.	24	.	1	.	.	.	2	2
Carex hirta	.	.	.	.	.	.	.	.	.	13	6	32	1	1	.	.	.	.	2
Agrostis stolonifera	.	.	.	.	.	.	1	.	.	1	.	20	1	.	.	.	.	1	2
Dianthus deltoides	.	.	.	.	1	1	1	.	.	2	.	21	.	.	.	.	.	.	3
Acetosa pratensis	.	1	1	2	1	.	.	.	1	14	.	31	.	1	.	.	2	4	3
Eryngium planum	.	.	.	.	.	.	.	.	.	.	.	14	.	.	.	.	.	.	.
Sanguisorba officinalis	.	.	.	.	.	.	.	.	.	.	.	16	.	.	.	.	.	3	.
Prunella vulgaris	.	.	.	.	3	.	.	.	.	1	.	25	1	1	.	2	1	6	4
Jacea pratensis	.	.	.	.	3	.	3	.	2	3	10	41	2	1	4	5	5	12	15
Leontodon autumnalis	.	.	.	.	.	.	1	.	1	1	3	21	.	.	.	.	.	5	2
Trifolium bonannii	.	.	.	.	.	.	.	.	.	.	.	12	.	.	.	.	.	.	.
Lysimachia nummularia	.	.	.	.	.	.	.	.	.	.	.	12	.	.	.	.	.	1	.
Galium boreale agg.	.	.	.	.	.	.	.	.	.	.	.	13	.	.	.	.	1	3	.
Festuca rubra agg.	.	1	.	.	1	.	1	.	.	5	.	24	.	1	.	.	2	6	11
Ononis arvensis	.	.	.	.	.	.	1	.	.	1	.	12	.	.	.	1	.	1	.
Cichorium intybus	.	.	.	.	1	.	2	.	1	4	3	19	1	1	.	.	.	1	3
Glechoma hederacea	.	.	.	.	.	.	.	.	.	1	3	12	.	1	.	.	.	2	1
Tithymalus esula	.	.	.	.	.	1	1	.	.	3	.	10	2	.	.	.	.	1	.
Cirsium arvense	.	.	.	.	.	1	1	.	.	.	.	9	2	2	.	1	.	1	1
Carex muricata agg.	.	.	3	1	7	1	.	.	.	2	.	11		.	.	.	.	1	2
Trifolium dubium	.	1	.	2	6	1	2	.	2	4	.	11	.	.	.	.	.	.	1
Dianthus armeria	.	1	1	1	.	.	.	2	.	5	.	9	.	.	.	.	.	.	2
Polygala vulgaris	.	.	.	3	1	.	1	.	.	3	.	11	.	1	.	1	1	4	10
Veronica chamaedrys agg.	.	.	3	5	9	2	3	.	5	8	.	19	.	.	.	.	2	15	17
Cluster 19: Degraded steppes and abandoned arable fields on loess																			
Agrimonia eupatoria	.	.	.	3	35	5	8	.	5	9	.	33	75	12	7	1	10	23	30
Rubus fruticosus s.l.	.	.	.	.	.	.	1	.	.	1	.	.	24	1	2	.	.	.	1
Picris hieracioides	.	2	2	2	9	4	6	2	.	2	.	5	45	14	2	4	5	13	15
Achillea collina	.	.	3	1	16	14	26	16	3	30	.	40	75	34	13	21	15	30	19

Cluster no.	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
No. of relevés	12	81	115	119	69	148	266	58	88	135	31	91	101	192	46	104	121	152	130
Marrubium peregrinum	.	.	.	.	.	.	1	.	.	.	.	.	12	3	.	.	.	.	.
Solidago canadensis	.	.	.	.	.	.	.	.	.	.	.	.	9	.	.	.	.	1	.
Lathyrus tuberosus	.	.	1	2	.	1	1	.	.	.	.	3	15	1	2	.	.	1	2
Jacea pannonica	.	.	.	2	.	.	.	.	.	1	6	13	24	4	15	.	2	7	1
Silene latifolia	.	2	1	1	1	1	2	.	.	7	.	.	15	2	.	.	.	.	1
Linaria vulgaris	.	1	1	.	1	.	2	.	2	1	6	2	17	1	.	.	1	.	5
Carduus acanthoides	.	2	1	.	1	3	4	.	1	4	3	12	21	9	.	2	.	1	4
Acosta biebersteinii	.	1	6	3	7	12	8	.	.	1	.	.	24	15	7	1	1	.	.
Linum perenne agg.	.	2	.	.	1	4	5	2	.	.	13	2	17	8	.	4	1	.	1
Elytrigia repens	.	1	4	6	3	10	11	.	.	16	3	12	26	7	7	4	2	4	7
Erigeron acris	.	1	.	.	.	.	1	.	.	2	6	.	9	.	.	1	.	3	4
Cluster 20: Continental steppe grasslands with *Festuca rupicola* on loess																			
Carex liparocarpos	8	1	.	.	.	1	1	.	.	.	6	.	2	18	.	4	.	1	2
Viola ambigua	.	.	.	2	.	3	1	19	.	.	.	.	19	26	9	6	19	1	.
Thymus glabrescens	8	11	24	8	14	23	22	41	8	10	26	1	40	58	30	38	32	8	14
Chrysopogon gryllus	8	9	.	.	.	3	2	2	1	1	.	1	2	15	4	2	1	1	2
Cluster 21: *Stipa tirsa* grasslands																			
Stipa tirsa	.	2	1	12	.	2	1	7	.	1	.	.	.	1	54	3	3	6	1
Inula hirta	.	2	3	23	4	2	.	5	1	.	.	.	.	10	52	12	23	9	.
Trommsdorffia maculata	.	.	1	5	.	1	1	2	2	.	.	.	.	2	30	4	9	12	1
Lathyrus latifolius	.	.	.	4	.	.	1	.	.	.	.	.	.	.	20	.	3	7	2
Dianthus pontederae	.	6	2	13	1	24	18	26	2	27	13	1	4	19	57	15	15	5	6
Campanula bononiensis	.	.	.	9	7	3	3	.	.	.	.	.	.	1	22	1	7	.	3
Filipendula vulgaris	.	6	3	13	3	7	4	7	1	7	16	26	22	27	54	27	25	31	15
Stipa dasyphylla	.	2	.	9	.	1	1	.	5	1	.	.	.	.	17	1	.	.	.
Danthonia alpina	.	.	.	1	.	.	.	.	.	1	.	.	.	.	9	.	.	1	.
Serratula radiata	.	.	.	.	.	.	.	.	.	.	.	.	1	2	9	.	.	.	.
Avenula praeusta	.	.	.	.	.	.	2	.	.	1	.	.	4	5	15	1	1	5	1
Eremogone micradenia	.	.	.	2	3	1	1	.	1	1	.	.	.	.	11	.	.	.	.
Genista tinctoria	.	1	6	16	4	1	2	.	3	1	.	1	.	5	30	.	20	18	15
Chamaecytisus albus	.	.	1	1	.	.	1	.	.	.	.	1	.	.	11	1	1	2	2
Lathyrus lacteus	.	4	.	1	.	.	.	.	.	.	.	.	.	.	9	.	2	1	.
Hieracium umbellatum	.	.	2	.	.	.	1	2	10	4	.	10	12	1	22	1	9	7	2
Echium russicum	.	5	.	2	.	1	1	.	.	1	.	.	.	.	9	1	2	5	.
Lembotropis nigricans	.	.	2	6	.	1	2	.	.	1	.	.	.	1	13	3	8	8	1
Cluster 23: Dry grasslands in transition to Pannonian broad-leaved meadow steppe																			
Chamaecytisus ratisbonensis	.	1	.	9	7	2	5	7	6	1	.	.	.	1	7	10	42	7	8
Orchis militaris	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	12	5	.
Anemone sylvestris	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	11	3	2
Stipa joannis	17	.	2	9	.	10	8	26	2	7	.	.	.	10	7	17	35	6	2
Linum tenuifolium	.	.	.	.	3	3	11	9	.	.	.	3	3	2	4	22	30	20	3
Onobrychis arenaria	.	.	.	.	.	.	2	5	.	1	.	.	.	4	9	6	17	11	2
Peucedanum alsaticum	.	.	.	1	.	3	1	12	.	1	.	.	6	8	15	1	19	1	1
Onobrychis viciifolia	.	.	.	1	.	.	1	.	.	.	.	.	.	1	2	.	11	6	4
Tithymalus tommasinianus	.	.	.	.	.	1	1	5	.	.	.	2	7	7	.	4	16	7	.
Rosa pimpinellifolia	.	.	2	7	3	1	1	.	1	1	.	.	.	.	7	4	13	1	.

Cluster no.	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
No. of relevés	12	81	115	119	69	148	266	58	88	135	31	91	101	192	46	104	121	152	130
Cluster 24: Dry grasslands in transition to Carpathian broad-leaved meadow steppe																			
Carex montana	.	.	.	2	1	1	.	.	.	.	.	.	.	.	.	.	4	21	2
Primula veris	.	.	.	2	1	2	1	.	.	1	.	1	.	.	2	.	1	22	3
Potentilla alba	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	12	.
Carex flacca	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	9	20	1
Prunella grandiflora	.	.	.	.	.	.	1	.	1	.	.	1	.	.	.	2	11	26	9
Salvia verticillata	.	.	1	3	13	3	8	5	.	.	.	2	.	1	4	4	11	36	15
Bromus pannonicus s.l.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	14	.
Carlina acaulis	.	1	.	.	.	1	9	.	15	.	6	.	.	1	.	14	20	38	22
Betonica officinalis	.	.	.	5	3	.	1	.	.	3	.	2	.	5	9	2	6	24	4
Cirsium pannonicum	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	6	13	.
Anthyllis vulneraria	.	.	3	2	32	19	29	5	7	2	23	7	1	1	2	15	17	53	23
Bromus erectus	.	.	.	1	.	12	20	7	2	4	6	3	24	9	4	16	16	39	12
Cruciata glabra	.	.	.	1	.	1	1	.	.	.	.	.	.	.	.	.	.	9	1
Astragalus danicus	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	5	1	10	.
Carex tomentosa	.	.	.	.	.	.	.	.	.	.	.	7	3	.	2	.	2	13	1
Carex caryophyllea	.	.	.	3	19	5	20	17	16	13	.	8	15	17	4	14	18	43	29
Carlina vulgaris s.l.	8	5	2	2	10	5	9	.	.	6	.	5	30	5	11	12	26	38	25
Rhinanthus serotinus agg.	.	.	.	.	.	.	.	.	.	.	.	1	.	1	.	2	1	9	.
Seseli annuum	.	.	3	1	.	5	6	3	6	8	3	4	25	19	4	11	6	32	21
Globularia punctata	.	1	.	1	4	2	11	16	.	.	3	.	.	1	.	22	15	29	5
Acinos alpinus	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	9	2
Asperula tinctoria	.	.	.	4	3	3	1	.	.	1	.	.	.	.	.	.	7	14	.
Carex michelii	.	.	.	8	14	3	2	.	.	.	.	1	.	5	17	7	16	22	4
Arabis hirsuta agg.	.	.	1	6	19	13	14	.	.	1	.	4	4	3	2	3	6	24	10
Trisetum flavescens	.	.	.	1	.	.	1	.	.	1	.	3	.	.	.	.	1	9	5
Tragopogon orientalis	.	2	.	.	4	1	2	.	.	2	3	9	5	5	.	1	2	15	4
Sanguisorba minor	50	26	12	9	32	55	61	24	20	24	42	15	18	12	9	35	47	66	46
Helianthemum nummularium agg.	25	2	2	16	22	22	26	5	3	4	.	2	1	2	9	28	35	41	21
Pilosella bauhinii	.	23	14	19	30	14	15	14	3	18	.	13	19	2	15	7	21	40	14
Inula salicina	.	.	.	2	1	.	1	.	.	.	.	.	.	1	7	8	6	11	.
Cluster 25: *Festuca rupicola* and *Carex humilis* dominated grasslands																			
Trifolium ochroleucon	.	.	.	2	.	.	1	.	.	3	.	9	.	.	.	.	.	1	11
Danthonia decumbens	.	.	.	1	.	.	1	.	9	1	.	2	.	.	.	.	.	5	11
Fragaria vesca	.	.	2	4	.	4	1	.	3	5	3	.	.	1	2	1	5	2	13
Diagnostic species common to two or more clusters																			
Veronica arvensis	50	11	2	2	3	10	7	2	3	30	10	16	.	2	.	.	.	.	2
Myosotis ramosissima	50	25	10	3	.	8	6	.	2	19	10	1	.	1	.	2	1	.	3
Veronica verna agg.	50	41	23	4	1	3	7	.	19	26	.	2	.	.	.	.	.	.	.
Arenaria serpyllifolia agg.	58	73	32	38	38	51	39	21	11	24	19	7	.	10	4	7	7	9	7
Thlaspi perfoliatum	.	32	3	11	14	26	18	5	1	5	.	.	1	7	4	1	4	1	3
Carduus collinus	.	35	19	6	26	5	1	.	.	.	.	.	.	.	7	.	2	.	.
Geranium columbinum	.	27	6	1	17	6	2	.	.	5	.	2	.	.	4	.	1	1	2
Lactuca perennis	.	21	14	8	17	5	1	.	.	.	.	1	.	.	2	.	.	1	.
Cota tinctoria	.	22	17	21	6	10	2	.	.	1	.	.	.	3	2	1	.	1	1
Acinos arvensis	8	54	50	31	35	44	39	28	5	5	3	7	6	6	.	13	5	5	15
Poa pannonica	.	15	26	8	.	.	.	.	.	.	.	.	.	.	4	.	.	.	.

Cluster no.	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
No. of relevés	12	81	115	119	69	148	266	58	88	135	31	91	101	192	46	104	121	152	130
Hylotelephium maximum agg.	.	5	37	48	1	7	2	.	2	4	.	.	1	3	9	.	1	1	1
Allium senescens subsp. *montanum*	.	4	23	25	.	13	11	.	1	4	.	1	.	.	.	3	4	6	5
Medicago prostrata	.	1	25	1	17	3	2	.	3	1	.	.	26	9	7	.	.	1	2
Sempervivum matricum	.	1	17	.	19	1	.	.	.	.	.	.	.	.	.	.	.	.	.
Steris viscaria	.	1	10	26	.	.	2	.	9	31	.	5	.	.	9	.	2	.	6
Geranium sanguineum	.	5	8	65	12	3	2	.	5	2	.	1	.	.	26	1	29	15	2
Vincetoxicum hirundinaria	.	.	5	31	17	7	4	3	1	1	.	.	4	4	11	5	29	11	3
Trifolium alpestre	.	6	8	40	7	7	6	3	17	11	.	2	2	3	35	9	9	10	8
Rosa gallica	.	2	3	17	4	3	.	.	1	2	.	.	.	1	26	.	2	3	2
Melica ciliata	42	9	23	14	52	26	10	.	.	1	.	.	.	2	2	10	2	2	1
Erysimum odoratum	.	.	3	8	38	22	6	9	1	.	.	.	.	1	.	1	3	6	2
Thymus pannonicus	.	51	15	47	67	39	31	59	16	47	.	21	19	15	30	23	12	22	25
Campanula sibirica	.	.	2	8	45	1	4	28	.	1	.	.	1	4	4	25	13	7	2
Alyssum montanum	.	1	6	6	41	12	27	2	6	1	.	.	.	.	4	10	3	2	1
Hippocrepis comosa	.	.	.	.	23	3	3	.	.	.	.	1	.	.	2	2	2	30	5
Vicia angustifolia	.	4	1	1	20	5	2	.	1	23	.	9	2	1	.	1	1	5	7
Medicago falcata	.	14	3	23	20	39	55	55	16	14	6	12	11	46	11	35	48	47	28
Seseli hippomarathrum	.	.	.	.	3	7	15	62	17	.	.	.	.	8	.	32	22	4	3
Carex supina	.	2	.	3	.	1	2	59	26	4	.	.	.	6	.	9	2	.	.
Pilosella echioides	.	.	.	2	.	.	3	29	28	2	.	1	3	1	.	3	.	.	.
Potentilla verna agg.	25	67	30	47	58	57	72	88	88	32	74	7	.	16	4	76	45	18	29
Phleum phleoides	.	4	13	44	13	17	26	74	64	31	6	3	11	19	26	20	21	25	20
Pseudolysimachion spicatum agg.	8	12	20	37	32	10	18	67	66	24	19	4	10	44	39	33	25	41	31
Artemisia campestris	.	4	10	29	13	18	30	66	43	23	6	.	7	22	4	21	12	7	4
Avenula pratensis	.	.	.	2	.	1	11	41	72	8	.	.	.	4	9	25	26	11	19
Silene otites agg.	.	7	2	13	13	18	22	40	50	13	16	.	1	20	.	31	4	1	4
Achillea setacea	.	.	.	.	.	1	5	22	19	7	13	.	1	7	.	3	.	.	2
Stipa pulcherrima	.	7	4	23	6	16	2	40	1	1	.	.	1	3	35	11	12	1	.
Securigera varia	.	9	5	15	30	18	33	50	7	16	10	9	51	22	7	20	24	39	36
Galium verum agg.	17	15	7	13	13	22	48	72	42	57	39	56	76	44	48	45	33	49	63
Jurinea mollis	.	.	.	1	6	9	3	33	.	.	.	.	.	14	7	18	27	1	.
Veronica prostrata	.	2	3	3	14	15	25	57	25	29	45	13	.	10	.	20	3	5	7
Achillea pannonica	.	2	6	16	13	14	27	53	3	4	58	9	5	35	35	21	37	7	10
Petrorhagia saxifraga	50	4	1	.	.	4	12	5	3	3	26	.	.	3	.	11	.	.	2
Hypericum perforatum	67	57	33	47	58	43	41	21	74	50	3	18	23	17	17	8	24	30	48
Linaria genistifolia	.	32	26	15	3	24	16	19	34	22	.	.	1	3	7	5	1	1	2
Dianthus carthusianorum	.	4	10	34	4	13	24	47	84	33	.	5	.	4	9	32	19	49	33
Euphrasia stricta agg.	.	1	2	.	3	1	5	7	26	6	.	1	4	1	.	7	2	3	20
Calluna vulgaris	.	.	.	.	.	.	.	2	12	4	.	.	.	.	.	.	.	.	10
Acetosella multifida agg.	.	6	14	5	6	1	4	22	60	54	.	9	.	.	.	2	.	.	12
Armeria vulgaris	.	.	.	.	.	.	.	3	33	13	.	.	.	.	.	4	.	.	.
Berteroa incana	.	5	2	.	1	2	5	2	17	24	.	1	.	1	.	.	.	.	2
Jasione montana	.	.	.	2	.	.	1	.	17	17	.	.	.	.	.	.	.	.	5
Arrhenatherum elatius	.	1	3	10	13	17	30	2	27	41	3	12	34	4	11	5	16	30	42
Trifolium campestre	.	22	9	5	13	9	11	.	26	47	35	15	5	1	2	.	.	3	17
Medicago lupulina	.	1	4	1	16	5	25	.	7	8	35	35	1	4	.	2	4	16	22
Festuca pseudovina	.	.	1	3	3	2	7	3	5	11	100	84	21	34	.	26	2	1	12
Cynodon dactylon	.	2	.	1	1	1	5	.	1	7	58	8	28	6	.	.	.	.	2

Cluster no.	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
No. of relevés	12	81	115	119	69	148	266	58	88	135	31	91	101	192	46	104	121	152	130
Nonea pulla	.	.	.	.	1	3	3	2	.	2	26	1	22	10	.	7	2	3	2
Dactylis glomerata agg.	.	1	3	5	.	3	8	5	.	10	48	18	82	34	9	8	29	36	26
Ononis spinosa	.	1	.	.	.	1	3	.	1	1	29	10	42	6	.	7	14	22	8
Trifolium pratense	.	.	.	.	.	1	2	.	.	4	26	70	2	.	.	.	.	11	15
Lolium perenne	.	.	.	.	1	1	2	.	.	2	16	25	.	1	.	.	.	1	3
Taraxacum sect. *Ruderalia*	.	.	.	1	3	1	3	.	.	4	19	42	3	3	.	1	2	6	8
Leucanthemum vulgare agg.	.	.	.	1	.	.	1	.	.	1	19	38	5	2	2	.	4	34	9
Festuca pratensis	.	.	.	.	7	.	2	.	.	1	13	43	22	1	.	.	2	18	8
Ranunculus polyanthemos	.	.	.	1	1	.	2	.	.	1	6	31	24	3	.	2	11	20	6
Agrostis capillaries	.	2	1	1	3	.	2	.	6	11	.	29	.	.	.	.	.	7	35
Luzula campestris s.l.	.	5	.	3	.	.	2	2	19	21	3	27	.	1	7	.	2	12	23
Rhinanthus minor	.	2	.	.	.	.	2	.	2	5	3	23	.	.	.	1	2	15	7
Poa pratensis agg.	.	7	9	26	33	29	42	14	33	59	13	65	70	47	30	18	24	32	49
Taraxacum serotinum	.	.	.	.	.	3	3	16	.	1	6	.	43	34	2	1	.	.	1
Tithymalus glareosus	.	1	.	.	.	5	1	2	.	.	.	.	42	49	20	.	1	1	1
Bromus inermis	.	.	.	3	1	3	2	7	.	1	.	.	39	33	20	3	17	1	4
Falcaria vulgaris	.	10	.	8	4	21	11	16	1	9	.	2	36	39	22	2	9	3	6
Agropyron pectinatum	.	4	1	.	.	.	.	.	.	.	.	.	18	14	.	.	.	.	.
Calamagrostis epigejos	.	1	.	3	.	.	2	3	1	13	.	2	20	3	24	2	6	5	9
Chamaecytisus austriacus	.	.	.	4	6	4	2	21	.	.	.	.	1	38	30	9	10	2	.
Seseli pallasii	.	.	.	2	.	1	1	12	.	.	.	1	13	23	17	1	3	.	.
Galium glaucum	.	31	23	43	7	38	11	29	3	4	6	.	20	51	52	24	40	14	5
Peucedanum cervaria	.	1	1	13	.	5	2	5	1	4	.	.	1	1	78	5	69	28	5
Inula ensifolia	.	2	.	15	10	14	6	12	.	.	3	.	2	8	67	37	83	38	2
Dictamnus albus	.	.	.	6	1	3	1	.	.	.	.	.	.	1	15	4	13	1	1
Pyrethrum corymbosum	.	.	1	13	1	1	1	.	1	1	.	.	1	1	22	5	29	14	1
Scorzonera hispanica	.	2	.	8	.	3	.	.	.	.	.	.	.	4	20	1	15	3	.
Trifolium montanum	.	2	1	8	6	3	3	2	11	7	3	24	7	5	41	3	12	44	18
Linum flavum	.	.	.	.	.	1	.	.	.	.	.	.	4	3	17	4	11	18	.
Serratula tinctoria	.	.	.	.	.	.	.	.	.	.	.	9	.	.	11	.	.	10	1
Trifolium rubens	.	.	.	3	.	.	.	.	.	.	.	.	.	.	9	.	1	10	.
Dorycnium pentaphyllum agg.	.	10	2	8	33	20	19	34	9	3	.	7	2	32	48	65	77	39	22
Bupleurum falcatum	.	.	.	8	1	13	15	7	7	.	.	.	1	3	13	40	65	26	6
Aster amellus	.	.	.	4	1	7	2	2	.	.	.	.	2	2	15	22	50	24	1
Brachypodium pinnatum	.	.	1	8	1	2	4	14	1	.	16	1	8	8	30	38	69	80	12
Viola hirta	.	.	1	4	19	7	5	2	.	2	.	2	3	5	4	12	31	53	21
Knautia arvensis agg.	.	.	.	.	1	1	7	5	1	9	10	8	22	12	9	4	31	57	25
Salvia pratensis	.	11	3	37	42	38	25	16	1	22	45	11	35	26	52	40	76	68	32
Plantago media	.	.	.	3	12	9	23	16	6	13	42	33	48	41	22	53	57	64	46
Anthericum ramosum	.	1	1	25	16	17	16	21	1	1	.	.	1	3	15	20	43	51	14
Thesium linophyllon	.	2	1	9	12	8	6	9	1	3	6	4	6	10	33	15	40	48	16
Campanula glomerata agg.	.	.	1	1	.	2	1	.	.	.	.	.	14	3	11	12	34	30	5
Briza media	.	.	.	1	.	.	2	.	2	1	.	15	7	2	7	4	24	61	28
Potentilla heptaphylla	.	2	2	5	7	6	6	.	.	7	.	21	1	.	9	2	6	51	28
Thymus pulegioides	.	.	4	4	3	7	3	9	8	5	3	10	.	1	.	1	2	30	32
Bromus hordeaceus	8	42	4	.	1	4	8	.	6	30	16	16	.	2	.	.	.	.	2
Vicia hirsuta	.	17	9	4	7	1	1	.	5	19	3	3	.	1	.	.	.	7	4
Trifolium arvense	8	60	36	28	7	11	12	21	38	44	10	5	.	1	2	.	.	.	12
Potentilla argentea agg.	8	43	33	23	7	10	8	.	14	73	19	46	1	2	2	2	.	1	20

Cluster no.	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
No. of relevés	12	81	115	119	69	148	266	58	88	135	31	91	101	192	46	104	121	152	130
Festuca pseudodalmatica	8	68	65	45	14	10	3	.	.	7	.	.	1	1	.	.	.	.	.
Sedum acre	.	42	44	18	41	22	20	2	16	13	3	7	.	.	4	.	1	3	3
Teucrium chamaedrys	58	43	33	82	91	84	64	31	15	25	16	8	14	56	65	53	72	63	49
Festuca valesiaca	33	37	23	29	54	76	72	98	65	40	.	13	53	23	17	31	17	5	8
Stipa capillata	8	7	2	11	6	26	27	66	39	2	10	.	27	61	7	51	16	1	5
Astragalus austriacus	.	.	.	.	.	3	3	41	.	.	23	1	12	37	.	31	17	1	1
Elytrigia intermedia s.l.	.	19	7	34	20	31	18	69	1	8	.	4	38	55	57	26	34	12	4
Salvia nemorosa	.	5	2	3	.	7	6	40	.	1	16	3	39	66	4	8	13	5	2
Scabiosa canescens	.	.	.	.	1	3	2	34	19	.	.	1	.	3	.	36	29	11	4
Carex humilis	.	6	1	29	30	13	30	57	62	8	.	.	3	18	28	79	63	39	25
Pilosella officinarum	.	7	3	8	19	19	39	2	55	33	52	31	18	6	7	28	17	22	54
Plantago lanceolata	.	5	2	3	38	9	35	2	48	51	58	73	40	10	7	6	6	32	54
Achillea millefolium s.l.	.	2	2	8	1	4	20	24	72	35	52	51	1	3	7	23	16	34	46
Lotus corniculatus agg.	.	6	1	3	7	11	29	16	40	21	55	78	33	18	7	20	25	55	49
Leontodon hispidus	.	.	.	1	4	3	6	.	7	5	10	34	29	3	7	7	17	47	40
Daucus carota	.	1	1	.	16	.	6	.	1	6	.	38	30	3	.	1	.	10	32
Colymbada sadleriana	.	.	1	2	.	2	2	2	.	.	.	.	40	33	33	1	2	2	1
Adonis vernalis	.	.	2	6	16	18	3	5	.	1	13	.	7	20	37	32	36	3	7
Polygala major	.	.	.	1	3	1	1	.	.	.	.	1	1	.	22	7	29	41	3
Colymbada scabiosa	.	.	.	15	4	14	18	36	7	5	13	3	3	15	17	49	81	65	17
Linum catharticum	.	2	.	.	6	2	3	.	2	1	.	5	.	1	.	5	26	45	25
Acosta rhenana	.	31	24	29	10	43	58	62	74	58	13	10	3	11	.	44	24	9	28
Astragalus onobrychis	.	1	1	1	.	12	16	59	2	3	6	1	34	39	2	39	41	2	4
Crinitina linosyris	.	7	3	37	6	15	7	48	7	6	.	.	1	30	74	62	60	7	3
Anthoxanthum odoratum	.	1	.	1	.	.	1	2	24	24	.	29	.	.	4	.	2	12	25
Festuca rupicola	8	10	4	24	43	30	44	19	31	62	.	32	22	41	76	64	80	86	78
Other species with constancy ≥ 10% in at least one cluster																			
Fragaria viridis	.	7	5	24	43	34	30	3	5	23	13	44	10	11	39	10	29	32	39
Scabiosa ochroleuca	.	10	7	27	43	32	48	52	12	28	19	7	58	36	22	56	51	60	52
Pimpinella saxifraga agg.	.	2	5	11	20	22	44	64	60	41	16	47	56	35	4	58	52	60	52
Eryngium campestre	25	74	9	35	55	52	66	72	77	54	45	29	59	67	48	38	44	16	55
Tithymalus cyparissias	58	78	60	70	83	75	64	53	26	70	32	23	46	32	35	62	64	74	72
Asperula cynanchica	8	44	27	50	68	57	64	79	81	31	32	20	55	46	33	59	66	72	56
Myosotis stricta	17	17	5	4	3	4	2	.	11	7	3	13	1	.	.	.	.	.	.
Allium flavum	.	31	20	22	30	34	20	7	26	7	.	.	1	.	.	15	14	.	2
Medicago minima	.	19	7	3	10	16	19	9	8	4	6	1	.	1	.	2	.	1	3
Erysimum diffusum agg.	.	9	3	1	1	8	6	9	.	9	6	.	4	6	.	4	4	.	2
Lepidium campestre	.	9	4	3	14	5	6	.	2	4	10	4	.	1	9	1	1	1	8
Galium mollugo agg.	.	4	2	7	9	7	4	5	.	4	.	7	8	4	2	1	3	11	11
Silene vulgaris	.	.	.	2	1	3	5	3	1	4	.	9	11	2	2	1	4	10	2
Avenula pubescens	.	2	.	2	1	3	7	.	1	10	.	3	11	7	4	4	9	16	11
Campanula rotundifolia agg.	.	1	3	.	3	1	5	2	15	5	.	.	3	1	.	9	12	14	12
Thalictrum minus	.	.	1	13	9	3	3	9	.	.	.	.	22	10	15	8	15	7	2
Festuca pallens	.	2	3	.	7	5	12	2	23	2	.	.	.	.	.	3	2	1	.
Scorzonera austriaca	.	1	.	1	14	3	5	5	.	1	.	.	.	.	2	6	8	.	.
Allium oleraceum	.	4	3	7	.	1	5	.	.	1	.	.	.	.	.	1	4	3	1
Orthantha lutea	.	.	.	6	.	2	3	10	11	2	.	.	.	6	4	7	14	7	2

This alliance represents open dry grasslands on shallow near-neutral to alkaline soils, which develop mostly over limestone or dolomite. Summer droughts are crucial for the establishment of this vegetation. It is dominated by narrow-leaved tussocky graminoids, in particular *Carex humilis* and *Festuca pallens*. Its distribution range includes the colline belt of the peri-Carpathian mountain ranges, the Inner-Carpathian basins (intermontane basins located in central and northern Slovakia) and the Dunántúli- and Északi-középhegység Mts (Transdanubian Range and Northern Range) in Hungary.

Festucion valesiacae Klika 1931 (Clusters 7–14, 17, 19–25)

Syn.: *Festucion rupicolae* Soó 1940 corr. 1964, *Asplenio septentrionalis-Festucion pallentis* Zólyomi 1936 corr. Soó 1957

Number of relevés: 1745

Diagnostic species: *Achillea collina*, ***A. pannonica***, *Acinos arvensis*, *Adonis vernalis*, *Alyssum alyssoides*, *Arenaria serpyllifolia* agg., *Astragalus austriacus*, *A. onobrychis*, *Bothriochloa ischaemum*, *Bromus inermis*, *Chamaecytisus austriacus*, *Crinitina linosyris*, *Dorycnium pentaphyllum* agg., *Elytrigia intermedia* s.l., *Eryngium campestre*, *Falcaria vulgaris*, *Festuca pseudodalmatica*, *F. valesiaca*, *Galium glaucum*, *Inula oculus-christi*, *Koeleria macrantha* s.l., *Medicago falcata*, *Onobrychis arenaria*, *Poa pannonica*, *Salvia nemorosa*, *Scabiosa ochroleuca*, *Seseli pallasii*, *Stachys recta*, *Stipa capillata*, *S. tirsa*, *Taraxacum serotinum*, *Teucrium chamaedrys*, *Thymus glabrescens*

Constant species: *Asperula cynanchica*, *Eryngium campestre*, *Festuca rupicola*, *Koeleria macrantha* s.l., *Potentilla verna* agg., *Scabiosa ochroleuca*, *Teucrium chamaedrys*, ***Tithymalus cyparissias***

Dominant species: *Carex humilis*, *Festuca pseudodalmatica*, *F. pseudovina*, *F. rupicola*, *F. valesiaca*, *Stipa capillata*

This alliance includes narrow-leaved continental steppe grasslands dominated by tussocky fescues (*Festuca valesiaca*, *F. pseudodalmatica*, *F. pseudovina* and *F. rupicola*), *Carex humilis* and various species of *Stipa*. They grow on neutral to alkaline, usually base-rich soil over limestone, dolomite, fluvial sediments, loess and neo-volcanic bedrock, which is deeper than that supporting vegetation of the *Bromo pannonici-Festucion pallentis* alliance. These communities inhabit south- to west-facing slopes and flat surfaces. Most stands are of secondary origin, replacing former thermophilous forests, but some are probably remnants of the vast steppes that covered the area in the Pleistocene and early Holocene. Traditional low-intensity grazing enabled the steppe species to persist. Following the recent cessation of the traditional management many of these grasslands are changing towards more mesic vegetation.

Koelerio-Phleion phleoidis Korneck 1974 (Clusters 15 and 16)

Syn.: *Euphorbio-Callunion* sensu Mucina et Kolbek in Mucina et al. 1993 non Schubert ex Passarge 1964

Number of relevés: 223

Diagnostic species: ***Acetosella multifida* agg.**, *Achillea collina*, ***A. millefolium* s.l.**, *A. setacea*, ***Acosta rhenana***, ***Agrostis vinealis***, *Arabidopsis thaliana*, ***Armeria vulgaris***, *Artemisia campestris*, ***Avenula pratensis***, ***Berteroa incana***, *Bromus hordeaceus*, *Carex praecox*, *C. supina*, *Cerastium pumilum* agg., *C. semidecandrum*, *Chondrilla juncea*, *Cruciata pedemontana*, ***Dianthus carthusianorum***, *D. pontederae*, *Erodium cicutarium*, *Erophila verna* agg., ***Eryngium campestre***, *Euphrasia stricta* agg., *Festuca ovina* agg., ***F. valesiaca***, *Gagea bohemica*, *Galium verum* agg., *Genista pilosa*, *Helichrysum arenarium*, *Hypericum perforatum*, ***Jasione montana***, *Koeleria macrantha* s.l., *Linaria genistifolia*, *Myosotis scorpioides* agg., *M. stricta*, *Ornithogalum umbellatum* agg., *Petrorhagia prolifera*, *Peucedanum oreoselinum*, ***Phleum phleoides***, *Pilosella echioides*, *P. officinarum*, *Poa bulbosa*, ***Potentilla argentea* agg.**, *P. verna* agg., *Pseudolysimachion spicatum* agg., *Saxifraga bulbifera*, *Scleranthus perennis*, *Sedum rupestre*, *S. sexangulare*, *Silene otites* agg.,

Steris viscaria, *Thymus pannonicus*, *T. praecox*, ***Trifolium arvense***, ***T. campestre***, *Valerianella locusta*, *Verbascum phoeniceum*, *Veronica arvensis*, ***V. prostrata***, ***V. verna*** **agg.**, *Vicia angustifolia*, *V. hirsuta*, *V. lathyroides*, *Viola arvensis*

Constant species: *Acetosella multifida* agg., *Achillea millefolium* s.l., ***Acosta rhenana***, *Asperula cynanchica*, *Dianthus carthusianorum*, ***Eryngium campestre***, *Festuca rupicola*, *F. valesiaca*, *Galium verum* agg., *Hypericum perforatum*, ***Koeleria macrantha*** **s.l.**, *Phleum phleoides*, *Pilosella officinarum*, *Pimpinella saxifraga* agg., *Plantago lanceolata*, *Poa pratensis* agg., *Potentilla argentea* agg., *P. verna* agg., *Tithymalus cyparissias*, *Trifolium arvense*

Dominant species: *Festuca pseudovina*, *F. rupicola*, ***F. valesiaca***

This alliance conventionally encompasses dry grasslands that develop on acidic soils over granite, gneiss, quartzite and other types of acidic bedrocks. Although the species composition includes acidophilous plants, it is rather close to the *Festucion valesiacae* and *Bromion erecti* alliances. Communities that are assigned to this alliance are distributed from western to eastern Central Europe (France, Germany, Austria, the Czech Republic, western Slovakia) and may reach even further to the east. In the dendrogram (Fig. 2), clusters 15 and 16, which represent acidophilous dry grasslands, are embedded within the vegetation of *Festucion valesiacae*.

Description of clusters

Cluster 1. Grassland vegetation of cool and humid cliffs and rocky slopes with montane species

Syntaxonomical classification:

1. Transitions to *Saxifrago aizoi-Seslerietum calcariae* Klika 1941 nom. invers. propos.
2. Transitions to *Minuartio langii-Festucetum pallentis* (Sillinger 1933) Mucina ex Kliment et al. 2005

Number of relevés: 96

Diagnostic species: *Acinos arvensis*, *Aconitum anthora*, *Allium scorodoprasum*, *A. senescens* subsp. *montanum*, ***Asplenium ruta-muraria***, *A. trichomanes*, *Aster alpinus*, *Aurinia saxatilis*, *Bellidiastrum michelii*, *Bupleurum falcatum*, *Calamagrostis varia*, *Campanula carpatica*, ***C. rapunculoides***, *Cardaminopsis arenosa* agg., *Chamaecytisus hirsutus, Colymbada scabiosa*, *Convallaria majalis*, *Cotoneaster integerrimus*, *C. melanocarpus*, *Cyanus mollis*, ***C. triumfettii***, *Dianthus praecox* subsp. *praecox*, *Draba aizoides*, *Erysimum odoratum*, *E. wittmannii*, *Festuca pallens*, ***Galium mollugo*** **agg.**, *Geranium sanguineum*, ***Hieracium bupleuroides***, *H. murorum*, *Hylotelephium maximum* agg., *Inula ensifolia*, *Jovibarba globifera*, *Lactuca perennis*, *Laserpitium latifolium*, *Lembotropis nigricans*, *Libanotis pyrenaica*, *Lilium martagon*, *Origanum vulgare*, *Oryzopsis virescens*, ***Polygonatum odoratum***, *Pulsatilla slavica*, *Pyrethrum clusii*, ***Saxifraga paniculata***, ***Securigera varia***, *Sedum album*, *Sempervivum wettsteinii*, ***Seseli osseum***, *Sesleria albicans*, *Silene nemoralis*, ***Spiraea media***, ***Stachys recta***, *Tithymalus epithymoides*, *Veronica austriaca*, ***Vincetoxicum hirundinaria***, *Viola tricolor* agg.

Constant species: *Acinos arvensis*, *Anthericum ramosum*, *Asperula cynanchica*, *Asplenium ruta-muraria*, *Carex humilis*, *Cyanus triumfettii*, ***Festuca pallens***, *Helianthemum nummularium* agg., *Inula ensifolia*, ***Jovibarba globifera***, *Polygonatum odoratum*, *Potentilla verna* agg., *Securigera varia*, *Sedum album*, ***Seseli osseum***, *Stachys recta*, *Teucrium chamaedrys*, ***Tithymalus cyparissias***, ***Vincetoxicum hirundinaria***

Dominant species: *Carex humilis*, ***Festuca pallens***, *Inula ensifolia*

This cluster links the *Bromo pannonici-Festucion pallentis* alliance with those of *Diantho lumnitzeri-Seslerion* and *Astero alpini-Seslerion calcariae*. Due to the method of data selection used in this study the prevailing dominants are *Festuca pallens* and *Carex humilis,* although *Sesleria albicans* is also always present. This vegetation develops on rocky slopes with a cool and humid mesoclimate, which are usually situated in narrow river valleys and on north-facing cliffs in warm regions (e.g. the Bükk Mts: Zólyomi 1936,

Vojtkó 1996; Slovenský kras Mts; Vihorlat Mts: Michalko 1957). This vegetation occupies also the warmest habitats in the Carpathian mountain ranges with cool climates, such as the Slovenský raj Mts (Šmarda 1970, Petrík 1978), Strážovské vrchy Mts and Chočské vrchy Mts. It frequently occurs on limestone in the klippen belt between the Inner and Outer Western Carpathians (e.g. in the Biele Karpaty Mts and Pieniny Mts, mostly unpubl. data). A typical feature is the common occurrence of chasmophytes (e.g. *Asplenium* spp. and *Draba aizoides*), dealpine (e.g. *Saxifraga paniculata*) and montane species (e.g. *Aster alpinus*, *Bellidiastrum michelii*, *Campanula carpatica* and *Pyrethrum clusii*). The majority of stands in the Bükk Mts lack montane species, although chasmophytes are frequent. These relevés were often classified in *Campanulo divergentiformis-Festucetum pallentis* Zólyomi (1936) 1966 by their original authors, however, they noticeably differ from the relevés assigned to cluster 3.

Cluster 2. Various rocky grasslands with *Festuca pallens*

Number of relevés: 107

Diagnostic species: *Allium flavum*, *Arenaria serpyllifolia* agg., *Artemisia austriaca*, *Asplenium trichomanes*, *Festuca pallens*, *Geranium rotundifolium*, *Hesiodia montana*, *Jovibarba globifera*, *Melica ciliata*, ***Sedum album***

Constant species: *Allium flavum*, *Asperula cynanchica*, ***Festuca pallens***, ***Jovibarba globifera*****,** *Melica ciliata*, *Potentilla verna* agg., *Sanguisorba minor*, ***Sedum album***, *Seseli osseum*, *Thymus praecox*, *Tithymalus cyparissias*

Dominant species: *Festuca pallens*, *Potentilla verna* agg.

This cluster encompasses *Festuca pallens* dominated open rocky grasslands that lack the specialist species typical of clusters 3 and 6, which include vegetation from similar habitats. This vegetation occurs on limestone (W Slovakia and Hungary) and serpentine (SW Moravia). Since this cluster includes rather heterogeneous vegetation, it was not interpreted syntaxonomically. It includes untypical stands of *Poo badensis-Festucetum pallentis* (W Slovakia), *Campanulo divergentiformis-Festucetum pallentis* (N Hungary) and *Asplenio cuneifolii-Festucetum pallentis* Zólyomi 1936 corr. Kolbek in Moravec et al. 1995 (SW Moravia). This cluster might be an artifact of the numerical classification method used and a result of idiosyncracies in the structure of the data set.

Cluster 3. Rocky grasslands with *Festuca pallens* and *Carex humilis* at the north-eastern periphery of the Pannonian Basin

Syntaxonomical classification:

1. *Poo badensis-Caricetum humilis* (Dostál 1933) Soó ex Michálková in Janišová et al. 2007
   Syn.: *Potentilletum tommasinianae* Krajina 1936 (Art. 31, 43), *Poo badensis-Caricetum humilis* (Dostál 1933) Soó 1971 (Art. 2b)
2. *Campanulo divergentiformis-Festucetum pallentis* Zólyomi (1936) 1966
   Syn.: *Festucetum glaucae* Zólyomi 1933 (Art. 43), *Seslerio-Festucetum duriusculae pannonicae* Dostál 1933 (Art. 34a, 43), *Festucetum glaucae subcarpaticum* Zólyomi 1936 (Art. 34a, 43), *Campanulo xylocarpae-Festucetum pallentis* Petrík 1985 ms. (Art. 1)

Number of relevés: 152

Diagnostic species: *Allium flavum*, *Asplenium viride*, *Astragalus vesicarius*, *Campanula sibirica*, *C. xylocarpa*, *Cleistogenes serotina*, *Echium vulgare*, *Erysimum odoratum*, *Galium glaucum*, *Helianthemum nummularium* agg., *Iris pumila*, *Lactuca perennis*, ***Linaria pallidiflora***, *Melica ciliata*, *Minuartia rubra*, *Onosma tornensis*, *Orobanche caryophyllacea*, *Poa badensis*, ***Potentilla verna* agg.**, *Salvia pratensis*,

Sempervivum matricum, *Seseli osseum*, *Stachys recta*, *Stipa joannis*, *Taraxacum* sect. *Erythrosperma*, *Teucrium chamaedrys*, *Tithymalus cyparissias*, *Verbascum lychnitis*, *Veronica austriaca*

Constant species: *Allium flavum*, *Anthericum ramosum*, ***Asperula cynanchica***, *Campanula sibirica*, ***Carex humilis***, ***Festuca pallens***, ***Helianthemum nummularium* agg.**, *Jovibarba globifera*, *Koeleria macrantha* s.l., *Melica ciliata*, ***Potentilla verna* agg.**, *Salvia pratensis*, *Scabiosa ochroleuca*, ***Seseli osseum***, *Stachys recta*, ***Teucrium chamaedrys***, ***T. montanum***, ***Tithymalus cyparissias***

Dominant species: ***Carex humilis***, *Festuca pallens*, *Potentilla verna* agg., *Stipa joannis*

These open or semi-open dry grasslands occur on steep rocky slopes over limestone in karst areas (Aggteleki-karszt Mts, Drienčanský kras Mts, Slovenský kras Mts: Háberová et al. 1985, Miadok 1987, Dúbravková-Michálková et al. 2008; Fig. 6) and adjacent regions at the north-eastern fringes of the Pannonian Basin (Čierna hora: Jurko 1951, Bükk Mts: Zólyomi 1936). Accidentally, the cluster includes a few similar relevés from the western part of the study area. Besides the drought-adapted species typical of the *Festucion valesiace* alliance some mesophilous herbs are also present. A typical feature is the occurrence of endemics and sub-endemics (e.g. *Astragalus vesicarius* subsp. *albidus*, *Campanula sibirica* subsp. *divergentiformis*, *C. xylocarpa* and *Onosma tornensis*; Kliment 1999) and species with south-eastern and sub-mediterranean distributions (e.g. *Cleistogenes serotina* and *Linaria pallidiflora*).

Cluster 4. Submontane grasslands with *Carex humilis* and *Bromus pannonicus* s.l.

Syntaxonomical classification**:**

1. *Orthantho luteae-Caricetum humilis* Kliment et Bernátová 2000
   Syn.: *Caricetum humilis* Klika 1929 (Art. 31)
2. Transitions to *Festuco pallentis-Seslerietum calcariae* Futák 1947 corr. Janišová in Janišová et al. 2007 nom. invers. propos.
3. *Festuco pallentis-Brometum pannonici* (Zólyomi 1958) Soó 1959 corr. 1964 p. p. min.

Number of relevés: 64

Diagnostic species: ***Acinos alpinus***, ***Allium ochroleucum***, ***Anthericum ramosum***, *Anthyllis vulneraria*, ***Asperula tinctoria***, *Biscutella laevigata*, ***Brachypodium pinnatum***, ***Bromus pannonicus* s.l.**, *Bupleurum falcatum*, *Campanula rotundifolia* agg., *Carduus glaucinus*, *Carex humilis*, *Carlina acaulis*, *Cirsium pannonicum*, *Coronilla coronata*, *C. vaginalis*, *Cotoneaster tomentosus*, *Daphne cneorum*, *Dorycnium pentaphyllum* agg., *Erysimum wittmannii*, *Euphrasia rostkoviana* agg., ***Galium pumilum* agg.**, *Genista pilosa*, *Gentianella lutescens*, *Geranium sanguineum*, *Globularia punctata*, *Gymnadenia conopsea*, *Helianthemum nummularium* agg., *Hieracium bifidum*, *Hippocrepis comosa*, *Inula ensifolia*, *I. salicina*, *Kernera saxatilis*, *Leontodon incanus*, *Leucanthemum vulgare* agg., *Linum catharticum*, *L. tenuifolium*, *Minuartia langii*, *Ophrys insectifera*, *Phyteuma orbiculare*, *Platanthera bifolia*, *Polygala amara* agg., *Potentilla heptaphylla*, *Primula auricula*, *Pteridium aquilinum*, *Pulsatilla slavica*, *P. subslavica*, *Salvia verticillata*, *Senecio umbrosus*, *Sesleria albicans*, *Tephroseris integrifolia*, *Teucrium chamaedrys*, *T. montanum*, *Thalictrum minus*, *Thesium alpinum*, *Thymus pulcherrimus*, *Tithymalus cyparissias*, *Vincetoxicum hirundinaria*, *Viola hirta*

Constant species: *Acinos alpinus*, *Anthericum ramosum*, *Anthyllis vulneraria*, *Asperula cynanchica*, *Bupleurum falcatum*, *Carex humilis*, *Dorycnium pentaphyllum* agg., *Genista pilosa*, *Globularia punctata*, *Helianthemum nummularium* agg., *Hippocrepis comosa*, ***Inula ensifolia***, ***Leontodon incanus***, *Linum tenuifolium*, *Pimpinella saxifraga* agg., ***Potentilla heptaphylla***, *Salvia pratensis*, ***Sanguisorba minor***, ***Sesleria albicans***, ***Teucrium chamaedrys***, ***T. montanum***, *Thymus praecox*, ***Tithymalus cyparissias***, ***Vincetoxicum hirundinaria***

Dominant species: *Anthericum ramosum*, *Bromus pannonicus* s.l., ***Carex humilis***

This nearly closed vegetation represents the most mesic type of grassland within *Bromo pannonici-Festucion pallentis* (Fig. 4). *Bromus monocladus* and *Carex humilis* codominate and some montane species (e.g. *Biscutella laevigata*, *Minuartia langii* and

Phyteuma orbiculare) and Carpathian elements (e.g. *Erysimum wittmannii*, *Gentianella lutescens*, *Primula auricula*, *Pulsatilla slavica* and *P. subslavica*) are present. Some slightly xerophilous herbaceous plants are also always present. This community occurs on limestone in the Inner-Carpathian basins of NW and central Slovakia (Turčianska kotlina Basin: Kliment & Bernátová 2000, Žilinská kotlina Basin; Fig. 6) and some central Carpathian mountain ranges (Nízke Tatry Mts, Strážovské vrchy Mts: Klika 1929a, b, Bosáčková et al. 1974, Fajmonová 1995). Similar grasslands with slightly xerophilous species, yet lacking the Carpathian and montane elements, classified as *Festuco pallentis-Brometum pannonici* by Zólyomi (1958), were found at a few sites on dolomites in the Dunántúli-középhegység Mts, HU. Other relevés of this association from drier sites were assigned to cluster 6 in the current analysis. Similar, geographically isolated grasslands occur also on Bisamberg, a flysch hill near Vienna.

Cluster 5. Rocky grasslands on dolomite in the Dunántúli-középhegység Mts (Hungarian Transdanubian Range)

Syntaxonomical classification:

1. *Seselio leucospermi-Festucetum pallentis* Zólyomi 1936 corr. 1966 nom. invers. propos.
   Syn.: *Stipo-Festucetum pallentis* (Zólyomi 1950) Soó 1964 (syntax. syn.), *Stipo eriocaulis-Festucetum pallentis* (Zólyomi 1958) Soó 1964 (phantom name)
2. *Stipo-Caricetum humilis* Soó 1930[1]
   Syn.: *Carici humilis-Chrysopogonetum grylli* Soó 1930 nomen nudum (Art. 2b), *Chrysopogono-Caricetum humilis* (Soó 1930) Zólyomi 1950 (Art. 2b, 7), *Caricetum humilis balatonicum* Soó (1930) 1964 (Art. 3n), *Chrysopogono-Caricetum humilis* (Soó 1930) 1971 (Art. 3n), *Chrysopogono-Caricetum humilis balatonicum* Zólyomi 1958 (Art. 34a), *Chrysopogono-Caricetum humilis* Zólyomi (1950) 1958 (phantom name)

Number of relevés: 64

Diagnostic species: ***Aethionema saxatile***, ***Allium moschatum***, *Alyssum tortuosum*, *Arenaria serpyllifolia* agg., ***Artemisia alba***, *Astragalus vesicarius*, *Brassica elongata*, *Carex humilis*, ***C. liparocarpos***, ***Cerastium brachypetalum* agg.**, ***Chrysopogon gryllus***, ***Dianthus plumarius* subsp. *regis-stephani***, *D. serotinus*, *Draba lasiocarpa*, *Erophila verna* agg., *Festuca laevigata*, ***Fumana procumbens***, ***Globularia punctata***, *Gypsophila fastigiata*, ***Holosteum umbellatum***, ***Hornungia petraea***, *Linum tenuifolium*, ***Melampyrum nemorosum***, ***Minuartia setacea***, *M. verna* agg., *Orthantha lutea*, ***Paronychia cephalotes***, ***Poa bulbosa***, *Reseda phyteuma*, ***Rhodax canus***, *Sanguisorba minor*, *Saxifraga tridactylites*, *Scabiosa canescens*, ***Scorzonera austriaca***, *Seseli hippomarathrum*, ***S. leucospermum***, ***Silene otites* agg.**, ***Stipa eriocaulis***, *Teucrium montanum*, *Thymus praecox*, ***Tithymalus seguierianus***

Constant species: ***Anthericum ramosum***, *Anthyllis vulneraria*, *Arenaria serpyllifolia* agg., *Asperula cynanchica*, ***Carex humilis***, ***Festuca pallens***, ***Fumana procumbens***, ***Globularia punctata***, *Hornungia petraea*, *Jovibarba globifera*, *Linum tenuifolium*, ***Minuartia setacea***, ***Rhodax canus***, ***Sanguisorba minor***, ***Scorzonera austriaca***, ***Seseli leucospermum***, *Silene otites* agg., *Stipa eriocaulis*, ***Teucrium montanum***, ***Thymus praecox***, ***Tithymalus seguierianus***

Dominant species: *Carex humilis*, *Melampyrum nemorosum*, *Stipa eriocaulis*

These are the most thermophilous grasslands of the *Bromo pannonici-Festucion pallentis* alliance, which are strongly associated with base-rich soils (Fig. 3, 4). The endemic (*Seseli leucospermum*) and sub-endemic taxa (*Dianthus plumarius* subsp. *regis-stephani*) of the Pannonian region and several sub-mediterranean species (e.g. *Chrysopogon gryllus*,

[1] Nomenclature note: Soó (1930: 28–31) validly described the *Stipo joannis-Caricetum humilis* association, based on a synoptic table. Since several *Stipa* species occur in the area in which Soó sampled relevés used for the synoptic table and some of them were not correctly distinguished in older literature, the determination of *Stipa joannis* in Soó (1930) needs revision. Until this is done, we use the association name in the form *Stipo-Caricetum humilis*.

Fumana procumbens, *Paronychia cephalotes* and *Stipa eriocaulis*) are included in this association. The sites are restricted to the south-facing dolomite slopes of the Dunántúli középhegység Mts, HU (Dobolyi et al. 1991, Kun & Ittzés 1995; Fig. 6). These grasslands persist because of the constant presence of open areas, which result from the highly variable micro-topography of the crumbling dolomite bedrock. A few relevés with a high cover of *Chrysopogon gryllus* were classified as *Stipo-Caricetum humilis* Soó 1930 (syn. *Chrysopogono-Caricetum humilis*) by their original author (Rédei unpubl.).

Cluster 6. Calcareous rocky grasslands with *Carex humilis* and *Festuca pallens* at the western periphery of the Western Carpathians

Syntaxonomical classification:

1. *Festuco pallentis-Caricetum humilis* Sillinger 1930 corr. Gutermann et Mucina 1993
   Syn.: *Caricetum humilis* Podpěra 1928 (Art. 36), *Scabioso suaveolentis-Caricetum humilis* Klika 1931 (syntax. syn.), *Caricetum humilis praecarpaticum* (Klika 1931) Soó 1945 (Art. 29c, 34a), *Festuco duriusculae-Teucrietum montani* Futák 1947 (syntax. syn.)
2. *Poo badensis-Festucetum pallentis* Klika 1931 corr. Zólyomi 1966 nom. invers. propos.
   Syn.: *Festucetum glaucae* Podpěra 1928 (Art. 2b, 36, 43), *Festucetum glaucae* Sillinger 1930 (Art. 36, 43), *Festucetum glaucae pannonicum moravicum* (Sillinger 1930) Zólyomi 1936 (Art. 34a, 43), *Minuartio montanae-Festucetum glaucae* Klika 1937 (Art. 43), *Festuco duriusculae-Poetum badensis* Klika (1931) 1939 (Art. 29, 43), *Sempervivetum soboliferi* Korneck 1975 (syntax. syn.)
3. *Festuco pallentis-Brometum pannonici* (Zólyomi 1958) Soó 1959 corr. 1964 p. p. max.
   Syn.: *Festuco glaucae-Brometum erecti archimatricum* Zólyomi 1958 (Art. 34a, 43), *Festuco pallentis-Brometum pannonici* Zólyomi 1958 (phantom name), *Festuco pallentis-Brometum pannonici* Zólyomi (1942) 1951 corr. Soó 1964 (Art. 2b, 7), *Seselio leucospermi-Brometum pannonici* (Mészáros-Draskovits 1967) Borhidi 1996 (syntax. syn.)

Number of relevés: 144

Diagnostic species: *Alyssum montanum*, *Carex humilis*, *Dianthus praecox* subsp. *lumnitzeri*, *Fumana procumbens*, *Genista pilosa*, *Globularia punctata*, *Helichrysum arenarium*, *Jurinea mollis*, *Leontodon incanus*, *Linum dolomiticum*, *L. tenuifolium*, ***Rhodax canus***, *Scorzonera austriaca Teucrium montanum*, *Thymus praecox*, *Viola rupestris*

Constant species: *Anthericum ramosum*, *Asperula cynanchica*, ***Carex humilis***, ***Festuca pallens***, *Genista pilosa*, *Globularia punctata*, *Helianthemum nummularium* agg., *Jovibarba globifera*, *Leontodon incanus*, *Linum tenuifolium*, ***Rhodax canus***, ***Sanguisorba minor***, *Seseli osseum*, ***Teucrium montanum***, ***Thymus praecox***, *Tithymalus cyparissias*

Dominant species: ***Carex humilis***, *Festuca pallens*, *Genista pilosa*

These open short-growing grasslands are dominated by *Carex humilis* and *Festuca pallens*, and contain numerous chamaephytes (e.g. *Fumana procumbens*, *Helianthemum nummularium* agg., *Rhodax canus* and *Thymus praecox*) and vernal ephemeral annuals. The grasslands occur on limestone and dolomite outcrops with shallow soil, at low altitudes in mountain ranges located at the western periphery of the Western Carpathians, such as the Považský Inovec Mts (Maglocký 1979, Michálková 2007a), S part of the Strážovské vrchy Mts (Futák 1947), Malé Karpaty Mts (Klika 1937), Pavlovské vrchy Hills (Klika 1931) and Hainburger Berge Hills (Waitzbauer 1990; Fig. 6). The vegetation is restricted to south- to west-facing slopes and warm hill plateaus. The area of these grasslands was increased by grazing in the past; however, now they are only grazed by wild animals, such as deer and mouflon, at most sites. This cluster also includes some relevés from the Budai-hegység Hills and other areas located west of the Danube river in Hungary. At most of these sites vegetation typical of cluster 5 is also found, and it is likely that the major reason for the separation of these relevés into clusters 5 and 6 is the accidental

absence of endemic and sub-mediterranean species typical of *Seselio leucospermi-Festucetum pallentis* in the relevés assigned to cluster 6. Cluster 6 also includes a few Hungarian relevés dominated by *Bromus pannonicus*, which represent the *Festuco pallentis-Brometum pannonici* association (Zólyomi 1958, Kun unpubl., Mészáros-Draskovits 1967). This cluster also includes some relevés from the serpentine outcrops near Mohelno in SW Moravia, which were assigned to *Euphorbio-Festucetum pallentis* (Zlatník 1928) Korneck 1974 and *Dorycnio sericei-Caricetum humilis* Zlatník 1928 in a local classification (Chytrý & Vicherek 1996). Few relevés from the eastern fringes of the Alps, which belong to *Fumano-Stipetum eriocaulis* Wagner 1941, are also included. This association was assigned to the *Diantho lumnitzeri-Seslerion* alliance by Mucina & Kolbek (1993). For this reason, most of its relevés were not included in our data set. However, given the close floristic relationship between *Fumano-Stipetum eriocaulis* and the associations *Festuco pallentis-Caricetum humilis* and *Poo badensis-Festucetum pallentis*, the syntaxonomical position of this community should be reviewed in the future.

Cluster 7. Open grasslands on alluvial soils along the Danube river

Syntaxonomical classification: *Teucrio botryos-Andropogonetum ischaemi* Sauberer et Wagner in Sauberer 1942

Number of relevés: 12

Diagnostic species: ***Apera interrupta***, *Arenaria serpyllifolia* agg., ***Bothriochloa ischaemum***, ***Cerastium pumilum* agg.**, *Eragrostis minor*, ***Erophila verna* agg.**, *Hypericum perforatum*, *Lycopodioides helveticum*, *Melica ciliata*, ***Myosotis ramosissima***, ***Petrorhagia saxifraga***, *Pilosella piloselloides*, ***Saxifraga tridactylites***, *Sedum sexangulare*, ***Teucrium botrys***, ***Veronica arvensis***, ***V. verna* agg.**

Constant species: *Apera interrupta*, *Arenaria serpyllifolia* agg., ***Bothriochloa ischaemum***, ***Cerastium pumilum* agg.**, ***Erophila verna* agg.**, ***Hypericum perforatum***, *Melica ciliata*, *Myosotis ramosissima*, *Petrorhagia saxifraga*, *Sanguisorba minor*, ***Saxifraga tridactylites***, *Sedum sexangulare*, *Teucrium botrys*, *T. chamaedrys*, *Tithymalus cyparissias*, *Veronica arvensis*, *V. verna* agg.

Dominant species: ***Bothriochloa ischaemum***, *Festuca valesiaca*, *Teucrium chamaedrys*, *Trifolium arvense*

These open grasslands on alluvial sandy and fine-gravelly substrata are dominated by *Bothriochloa ischaemum* and include species typical of sandy soils (e.g. *Apera interrupta*, *Eragrostis minor* and *Petrorhagia saxifraga*) and vernal ephemeral annuals (e.g. *Cerastium pumilum* agg., *Erophila verna* agg. and *Saxifraga tridactylites*). This vegetation occurs mostly on alluvial terraces along the Danube river east of Vienna (Sauberer 1942, Margl 1973, Rotter 2006; Fig. 6).

Cluster 8. Semi-closed grasslands on volcanic bedrocks in the Inner Western Carpathians with *Festuca pseudodalmatica* and sub-mediterranean species

Syntaxonomical classification: *Inulo oculi-christi-Festucetum pseudodalmaticae* Májovský et Jurko 1956

Number of relevés: 81

Diagnostic species: *Acinos arvensis*, *Allium vineale*, *Arenaria serpyllifolia* agg., ***Bromus hordeaceus***, ***Carduus collinus***, ***Cerastium brachypetalum* agg.**, ***Cleistogenes serotina***, *Cota tinctoria*, ***Cruciata pedemontana***, *Erysimum crepidifolium*, ***Festuca pseudodalmatica***, ***Galium aparine* agg.**, *Geranium columbinum*, *Inula oculus-christi*, *Lactuca perennis*, *L. viminea*, *Lathyrus nissolia*, ***Leopoldia comosa***, *Linaria genistifolia*, ***Logfia arvensis***, *Medicago monspeliaca*, *Melica transsilvanica*, *Myosotis ramosissima*, ***Orlaya grandiflora***, *Orobanche coerulescens*, *Petrorhagia prolifera*, *Poa pannonica*, *Polycnemum arvense*, *P. majus*, *Potentilla argentea* agg., *Sedum acre*, *Setaria pumila*, *S. viridis*, *Thlaspi perfoliatum*, *Trifolium arvense*, *Turgenia latifolia*, ***Valerianella dentata***, *Veronica verna* agg., *Vicia hirsuta*, ***Viola kitaibeliana***, *V. tricolor*, *Xeranthemum annuum*

Constant species: *Acinos arvensis*, ***Arenaria serpyllifolia* agg.**, *Asperula cynanchica*, *Bothriochloa ischaemum*, *Bromus hordeaceus*, *Cerastium brachypetalum* agg., *Cruciata pedemontana*, *Echium vulgare*, ***Eryngium campestre***, ***Festuca pseudodalmatica***, *Hypericum perforatum*, *Koeleria macrantha* s.l., *Potentilla argentea* agg., ***P. verna* agg.**, *Sedum acre*, *Teucrium chamaedrys*, *Thymus pannonicus*, ***Tithymalus cyparissias***, *Trifolium arvense*, *Veronica verna* agg.
Dominant species: *Bothriochloa ischaemum*, *Cleistogenes serotina*, ***Festuca pseudodalmatica***, *F. valesiaca*

These thermophilous semi-closed dry grasslands are dominated by *Festuca pseudodalmatica* but there can also be a high cover of other grasses (e.g. *Bothriochloa ischaemum*, *Cleistogenes serotina* and *Festuca valesiaca*). Some of the diagnostic taxa have a sub-mediterranean distribution (e.g. *Cleistogenes serotina*, *Melica transsilvanica* and *Poa pannonica* subsp. *scabra*). Most localities are on neovolcanic bedrock in the Inner Western Carpathians in Central Slovakia in areas situated around the middle part of the Hron river valley and along the Ipeľ river (e.g. Pohronský Inovec Mts, Štiavnické vrchy Mts, Vtáčnik Mts: Májovský & Jurko 1958, Krupinská planina Plateau: Májovský & Jurko 1956, Hronská pahorkatina Hills and Ipeľská pahorkatina Hills: Vozárová 1990, Ipeľská kotlina Basin, Lučenecká kotlina Basin and Cerová vrchovina Hills; Fig. 6). Vegetation included in this cluster occurs on warm slopes at low altitudes. The cluster also accidentally includes a few relevés from non-volcanic substrata, namely from Permo-Carboniferous conglomerates in SW Moravia or alluvial sediments at lakes Balaton and Neusiedler See, and along the Danube and Ondava rivers.

Cluster 9. *Festuca pseudodalmatica* open rocky grasslands on volcanic bedrock

Syntaxonomical classification: *Festucetum pseudodalmaticae* Mikyška 1933 p. p. max.
Syn.: *Festucetum pseudodalmaticae* Domin 1929 nom. inval. (Art. 2b, 7), *Festucetum pseudodalmaticae* Domin 1931 nom. inval. (Art. 2b, 7), *Festucetum pseudodalmaticae* Sillinger 1931 nom. inval. (Art. 2b, 7), *Poetum scabrae* Zólyomi 1936 (syntax. syn.), *Minuartio frutescentis-Festucetum pseudodalmaticae* (Mikyška 1933) Klika 1938 (Art. 3f, 36), *Minuartio glomeratae-Festucetum pseudodalmaticae* Klika 1938 (syntax. syn.), *Potentillo arenariae-Festucetum pseudodalmaticae* Májovský 1955 nom. invers. propos. (syntax. syn.)

Number of relevés: 115
Diagnostic species: *Acinos arvensis*, *Allium senescens* subsp. *montanum*, *Asplenium septentrionale*, *A. trichomanes*, *Aurinia saxatilis*, *Cardaminopsis arenosa* agg., *Cystopteris fragilis*, *Festuca pseudodalmatica*, *Geranium lucidum*, *Hylotelephium maximum* agg., *Jovibarba globifera*, *Medicago prostrata*, ***Minuartia hirsuta***, ***Poa pannonica***, *Polypodium vulgare*, *Scilla drunensis*, *Sedum acre*, *Sempervivum matricum*, *Seseli osseum*, *Veronica hederifolia* agg., *Vulpia myuros*
Constant species: *Acinos arvensis*, ***Festuca pseudodalmatica***, *Sedum acre*, ***Seseli osseum***, *Tithymalus cyparissias*
Dominant species: ***Festuca pseudodalmatica***, *F. valesiaca*, *Poa pannonica*

These open rocky grasslands are dominated by *Festuca pseudodalmatica* and *Poa pannonica* (subsp. *scabra*). Succulents, chasmophytes and mosses occupy gaps between individuals of the dominant species and bare rock outcrops are also usually present. This vegetation is typical of shallow rocky soils over volcanic bedrock, mostly at low altitudes with only in few at altitudes over 750 m. It occurs in N Hungary (Mátra Mts: Kovács & Máthé 1964, Zempléni-hegység Mts: Simon 1977, Börzsöny Mts; Fig. 7), E Slovakia (Slánske vrchy Mts, Vihorlat Mts and Košická kotlina Basin: Májovský 1955) and the northern part of the neovolcanic area in central Slovakia (mountain ranges and basins around the upper Hron river valley, e.g. Kremnické vrchy Mts, Poľana Mts, Zvolenská kotlina Basin, Štiavnické vrchy Mts: Mikyška 1933). Relevés dominated by *Festuca pseudodalmatica* from the Burda Mts (Klika 1938, under the association name *Minuartio*

glomeratae-Festucetum pseudodalmaticae) were assigned to this cluster, although they contain some sub-mediterranean species. Accidentally, some species-poor relevés from calcareous bedrocks in the Pilis Mts (Szerdahelyi 1989) were also assigned to this cluster.

Cluster 10. Dry grasslands with thermophilous forest species

Syntaxonomical classification:
1. successional stages of various associations of the *Festucion valesiacae* alliance
2. *Festucetum pseudodalmaticae* Mikyška 1933 p. p. min.
3. *Stipetum tirsae* Meusel 1938 p. p. min.

Number of relevés: 119
Diagnostic species: *Allium senescens* subsp. *montanum*, *Cerasus fruticosa*, *Cota tinctoria*, *Festuca pseudodalmatica*, ***Geranium sanguineum***, ***Hylotelephium maximum* agg.**, *Origanum vulgare*, *Papaver dubium*, *Polygonatum odoratum*, *Potentilla recta*, *Rosa gallica*, *Stachys recta*, *Steris viscaria*, *Teucrium chamaedrys*, *Trifolium alpestre*, ***Verbascum chaixii* subsp. *austriacum***, *Vincetoxicum hirundinaria*
Constant species: *Asperula cynanchica*, *Festuca pseudodalmatica*, *Galium glaucum*, ***Geranium sanguineum***, *Hylotelephium maximum* agg., *Hypericum perforatum*, *Koeleria macrantha* s.l., *Phleum phleoides*, *Potentilla verna* agg., *Seseli osseum*, ***Stachys recta***, ***Teucrium chamaedrys***, *Thymus pannonicus*, ***Tithymalus cyparissias***, *Verbascum chaixii* subsp. *austriacum*
Dominant species: *Carex humilis*, *Elytrigia intermedia* s.l., ***Festuca pseudodalmatica***, *Geranium sanguineum*, *Stipa tirsa*

This heterogeneous cluster includes forest-steppe grasslands, usually located near the edges of thermophilous oak or oak-hornbeam forests. A mixture of steppe species, forest-fringe herbaceous plants and shrubs grow in these grasslands, most of which are of secondary origin. At some sites, however, they are probably the primary vegetation developed at the edges of thermophilous oak forests or in canopy openings within these forests. These grasslands often occur as a distinct part of vegetation zonation, which ranges from oak forest through thermophilous scrub and an herbaceous fringe to steppe grassland in the centre of the opening. A large portion of relevés come from the volcanic regions in E Slovakia and N Hungary (Vihorlat Mts: Michalko 1957, Košická kotlina Basin: Májovský 1954, Zempléni-hegység Mts: Sendtko 1997, Karancs Mts and Medves Mts: Csiky 2003, Mátra Mts: Garadnai unpubl.). These relevés are assigned to *Festucetum pseudodalmaticae* by the traditional classification. They contain some forest fringe species and were recorded on deeper soils than the relevés of this association assigned to cluster 9. The cluster also includes 12 relevés with *Stipa tirsa* from N Hungary (S part of the Zempléni-hegység Mts: Sendtko 1997, Börzsöny Mts – Ruzsás hegy and Pilis-Visegrádi-hegység Mts: Baráth 1964), which were previously classified as *Inulo hirtae-Stipetum tirsae* (Baráth 1964) Borhidi 1996. These nearly closed grasslands occur on steep slopes with shallow soil and include more drought-adapted species than related relevés included in cluster 21 (*Stipetum tirsae*). Since the overall species composition corresponds to *Stipetum tirsae* and these grasslands occur in the same areas as those of cluster 21, they are considered to be a single syntaxonomical unit. A few stands dominated by *Stipa* spp. were recorded on steep rocky slopes and edges of river valleys on gneiss or granite bedrock (e.g. the Dyje river valley, SW Moravia; Tichý et al. 1997).

Cluster 11. Steppe grasslands with *Festuca valesiaca* s.l. at the north-eastern periphery of the Pannonian Basin

Syntaxonomical classification: *Alysso heterophylli-Festucetum valesiacae* (Dostál 1933) Kliment in Kliment et al. 2000

Syn.: *Festucetum pseudodalmaticae calcicolum* Dostál 1933 (Art. 34), *Festucetum valesiacae pannonicum* (Dostál 1933) Klika 1939 (Art. 34), *Festucetum valesiacae* (Dostál 1933) Miadok 1987 (Art. 31), *Pulsatillo montanae-Festucetum rupicolae* (Dostál 1933) Soó 1964 corr. Borhidi 1997 (Art. 3f)

Number of relevés: 69

Diagnostic species: ***Achillea nobilis***, *Agrimonia eupatoria*, *Ajuga genevensis*, *Alyssum montanum*, *Asplenium ruta-muraria*, *Bromus arvensis*, *Bupleurum longifolium*, *Campanula sibirica*, *Carduus collinus*, *Convolvulus arvensis*, *Cyanus triumfettii*, *Echium vulgare*, ***Erysimum odoratum***, *Filago vulgaris*, *Fragaria moschata*, *Gasparrinia peucedanoides*, *Geranium columbinum*, *Hippocrepis comosa*, *Lactuca perennis*, *Linaria pallidiflora*, *Melica ciliata*, *Onosma pseudoarenarium* subsp. *tuberculatum*, *O. tornensis*, *Poa badensis*, *Prunella laciniata*, *Ranunculus bulbosus*, *Sedum acre*, *Sempervivum matricum*, *Stachys germanica*, *Teucrium chamaedrys*, *T. montanum*, *Thymus pannonicus*, *Valerianella rimosa*, *Verbascum lychnitis*, *Vicia angustifolia*

Constant species: ***Achillea nobilis***, *Alyssum montanum*, ***Asperula cynanchica***, *Campanula sibirica*, *Echium vulgare*, *Eryngium campestre*, *Festuca rupicola*, *F. valesiaca*, *Fragaria viridis*, *Hypericum perforatum*, ***Koeleria macrantha* s.l.**, *Melica ciliata*, *Potentilla verna* agg., *Salvia pratensis*, *Scabiosa ochroleuca*, *Sedum acre*, *S. sexangulare*, *Stachys recta*, ***Teucrium chamaedrys***, *T. montanum*, ***Thymus pannonicus***, ***Tithymalus cyparissias***

Dominant species: *Carex humilis*, *Festuca pseudodalmatica*, *F. rupicola*, ***F. valesiaca***, *Teucrium chamaedrys*

This association includes species-rich steppes dominated by *Festuca valesiaca* s.l. (*F. valesiaca* and *F. pseudodalmatica*), which is accompanied by other grasses (e.g. *F. rupicola*, *Koeleria macrantha* and *Melica ciliata*) and some endemic or sub-endemic taxa (*Campanula sibirica* subsp. *divergentiformis* and *Onosma tornensis*). This vegetation grows on humus-rich, shallow and slightly alkaline soils, usually near rock outcrops, which dessicate during dry periods in summer. Many sites are located on gentle slopes with limited soil erosion, mostly over limestone in the karst areas at the NE edge of the Pannonian Basin (Aggteleki-karszt, Drienčanský kras, Slovenský kras; Dostál 1933, Kliment et al. 2000, Dúbravková-Michálková et al. 2008; Fig. 7), and also in the Čierna hora Mts (E Slovakia) and Bükk Mts (Less 1998). Similar vegetation was described by Penksza (1998) in the Cserehát Mts (NE Hungary) as *Sedo acris-Festucetum valesiacae* Penksza 1998. Compared to *Alysso heterophylli-Festucetum valesiacae* it is more open pioneer vegetation characteristic of early successional stages. This cluster accidentally includes a few similar relevés from the western part of the study area (Malé Karpaty Mts, Strážovské vrchy Mts, Budai-hegység Hills – Odvas-hegy).

Clusters 12 & 13. Basal community of Central European dry grasslands dominated by *Festuca valesiaca* s.l.

Syntaxonomical classification:

1. *Festuco valesiacae-Stipetum capillatae* Sillinger 1930 p. p. max.
   Syn.: *Ranunculo illyrici-Festucetum valesiacae* Klika 1931 (syntax. syn.), *Erysimo erysimoidis-Festucetum valesiacae* Klika 1937 (syntax. syn.), *Medicagini minimae-Festucetum valesiacae* Wagner 1941 (syntax. syn.), *Cleistogeno-Festucetum sulcatae* Zólyomi 1958 (syntax. syn.), *Astragalo austriaci-Stipetum capillatae* Vicherek in Vicherek et Unar 1971 ms. (Art. 1), *Minuartio setaceae-Stipetum capillatae* Vicherek in Vicherek et Unar 1971 ms. (Art. 1), *Inulo oculi-christi-Festucetum valesiacae* Šmarda 1975 (syntax. syn.), *Allio montani-Festucetum valesiacae* Eijsink et al. 1978 (syntax. syn.), *Poo angustifoliae-Festucetum valesiacae* Zinöcker in Mucina et Kolbek 1993 (syntax. syn.)
2. *Koelerio macranthae-Stipetum joannis* Kolbek 1978 p. p. min.

Cluster 12

Number of relevés: 148
Diagnostic species: *Alyssum alyssoides*, *Erysimum odoratum*, *Festuca valesiaca*, *Minuartia rubra*, *Orobanche caryophyllacea*, *Sedum album*, *Teucrium chamaedrys*, *Thlaspi perfoliatum*
Constant species: *Acinos arvensis*, *Acosta rhenana*, *Arenaria serpyllifolia* agg., *Asperula cynanchica*, *Bothriochloa ischaemum*, *Eryngium campestre*, ***Festuca valesiaca***, *Hypericum perforatum*, ***Koeleria macrantha* s.l.**, *Potentilla verna* agg., *Sanguisorba minor*, *Sedum sexangulare*, *Stachys recta*, ***Teucrium chamaedrys***, ***Tithymalus cyparissias***
Dominant species: *Festuca pseudodalmatica*, ***F. valesiaca***, *Teucrium chamaedrys*

Cluster 13

Number of relevés: 266
Diagnostic species: *Acosta rhenana*, *Alyssum montanum*, *Festuca valesiaca*, *Medicago falcata*, *Sonchus asper*
Constant species: *Acosta rhenana*, ***Asperula cynanchica***, ***Eryngium campestre***, *Festuca rupicola*, ***F. valesiaca***, *Galium verum* agg., *Hypericum perforatum*, ***Koeleria macrantha* s.l.**, *Medicago falcata*, *Pimpinella saxifraga* agg., *Poa pratensis* agg., ***Potentilla verna* agg.**, ***Sanguisorba minor***, *Scabiosa ochroleuca*, *Sedum sexangulare*, ***Teucrium chamaedrys***, ***Tithymalus cyparissias***
Dominant species: *Bothriochloa ischaemum*, *Carex humilis*, *Festuca rupicola*, ***F. valesiaca***, *Potentilla verna* agg.

Both clusters 12 and 13 include vegetation characteristic of *Festuco valesiacae-Stipetum capillatae*, which can be considered a basal community of the *Festucion valesiacae* alliance (Fig. 7). Both clusters have a central position along the main environmental gradients of this data set, which correspond to soil nutrients, moisture and soil base status (Fig. 3). This explains why they are split at a relatively high level of dissimilarity. This vegetation contains many generalist species of Central European dry grasslands and a few specialists. It is distributed throughout the study area, but is slightly more common in the western part. In each country, various names have been used for this vegetation. The association was first described in the Považský Inovec Mts (Sillinger 1930; see also Maglocký 1979 and Michálková 2007a) and also studied in other areas (e.g. Klika 1931, Eijsink et al. 1978, Szerdahelyi 1989, Unar 2004). The relevés included in cluster 12 represent degraded steppes on sloping ground, which were probably heavily grazed in the past. The soil depth varies due to a mosaic of rock outcrops and patches with deeper soils (Penksza et al. 1995). The cluster also includes some relevés of grasslands dominated by *Stipa joannis* and *S. pulcherrima,* which were classified as *Koelerio macranthae-Stipetum joannis* by Chytrý et al. (2007). Cluster 13 comprises mostly dry grasslands of secondary origin formed by tussocky grasses on somewhat deeper soils.

Cluster 14. Open grasslands on loess with *Festuca valesiaca* and relict species of continental steppes

Syntaxonomical classification:
1. *Astragalo exscapi-Crambetum tatariae* Klika 1939 nom. invers. propos.
2. *Avenastro besseri-Stipetum joannis* Klika 1951 corr. Kolbek in Moravec et al. 1983
3. *Koelerio macranthae-Stipetum joannis* Kolbek 1978 p. p. max.
   Syn.: *Genisto tinctoriae-Stipetum joannis* Tichý et al. 1997 (syntax. syn.), *Inulo oculi-christi-Stipetum pulcherrimae* Tichý et al. 1997 (syntax. syn.)
4. *Festuco valesiacae-Stipetum capillatae* Sillinger 1930 p. p. min.

Number of relevés: 58

Diagnostic species: *Achillea pannonica*, *A. setacea*, *Acosta rhenana*, ***Artemisia campestris***, *Astragalus austriacus*, ***A. exscapus***, ***A. onobrychis***, *Avenula pratensis*, *Bothriochloa ischaemum*, *Campanula sibirica*, ***Carex supina***, *Corothamnus procumbens*, ***Crambe tataria***, *Crinitina linosyris*, *Echinochloa crus-galli*, *Elytrigia intermedia* s.l., ***Festuca valesiaca***, *Galium verum* agg., *Helictotrichon desertorum* subsp. *basalticum*, *Iris pumila*, *Jurinea mollis*, *Koeleria macrantha* s.l., *Medicago falcata*, *Minuartia setacea*, *Oxytropis pilosa*, *Phleum phleoides*, ***Pilosella echioides***, *Potentilla verna* agg., *Pseudolysimachion spicatum* agg., *Salvia nemorosa*, *Scabiosa canescens*, *Securigera varia*, *Senecio jacobaea*, ***Seseli hippomarathrum***, *Silene otites* agg., *Stipa capillata*, *S. pulcherrima*, *Thymus pannonicus*, *Verbascum phoeniceum*, *Veronica prostrata*

Constant species: *Achillea pannonica*, ***Acosta rhenana***, ***Artemisia campestris***, ***Asperula cynanchica***, *Astragalus austriacus*, *A. onobrychis*, *Avenula pratensis*, *Bothriochloa ischaemum*, *Carex humilis*, *C. supina*, *Crinitina linosyris*, *Dianthus carthusianorum*, ***Elytrigia intermedia* s.l.**, ***Eryngium campestre***, ***Festuca valesiaca***, ***Galium verum* agg.**, ***Koeleria macrantha* s.l.**, *Medicago falcata*, ***Phleum phleoides***, ***Pimpinella saxifraga* agg.**, ***Potentilla verna* agg.**, ***Pseudolysimachion spicatum* agg.**, *Scabiosa ochroleuca*, *Securigera varia*, ***Seseli hippomarathrum***, ***Stipa capillata***, *Thymus glabrescens*, *T. pannonicus*, *Tithymalus cyparissias*, *Veronica prostrata*

Dominant species: *Festuca valesiaca*, ***Stipa capillata***, ***S. pulcherrima***

The semi-open steppes of *Astragalo exscapi-Crambetum tatariae* occur on deep soils over loess or calcareous Palaeogene sandstone in S Moravia (Vicherek & Unar 1971) and some sites in E Austria and N Hungary. They are often found at recently disturbed sites, such as rabbit colonies, landslides or even abandoned fields (Fig. 7). When left undisturbed for a few years the vegetation at these sites may change into the closed type similar to that of the *Cirsio-Brachypodion pinnati* alliance (clusters 22 and 23). They are mostly dominated by *Festuca valesiaca*. A typical feature is the presence of competitively weak and rare continental steppe species such as *Astragalus exscapus*, *Carex supina*, *Crambe tataria* and *Iris pumila*, which are, however, not present at all localities. Some stands are co-dominated by the relict continental grass *Helictotrichon desertorum* subsp. *basalticum* (Mikulov in S Moravia, Drasenhofen in Lower Austria; Klika 1931, Gauckler 1969, Kolbek & Boublík 2006). This cluster also includes some relevés from S Moravia (e.g. Pouzdřany and Čejč) with *Stipa pulcherrima* dominant and the constant presence of continental steppe species. They were classified as *Koelerio macranthae-Stipetum joannis* by Chytrý et al. (2007). Besides open grasslands with rare relict species this cluster also includes more closed and successionally advanced stands corresponding to *Festuco valesiacae-Stipetum capillatae*; however, unlike relevés of this association included in clusters 12 and 13, these contain more specialist species associated with the continental steppes.

Cluster 15. Dry grasslands with *Festuca valesiaca* on acidic soils

Syntaxonomical classification: *Avenulo pratensis-Festucetum valesiacae* Vicherek et al. in Chytrý et al. 1997
Syn.: *Acetosello tenuifoliae-Festucetum valesiacae* Vicherek 1962 prov. (Art. 3b), *Agrostio pusillae-Festucetum valesiacae* Vicherek in Vicherek et Unar 1971 ms. (Art. 1)

Number of relevés: 88

Diagnostic species: ***Acetosella multifida* agg.**, *Achillea millefolium* s.l., *A. setacea*, *Acosta rhenana*, ***Agrostis vinealis***, *Anthoxanthum odoratum*, ***Armeria vulgaris***, *Artemisia campestris*, *Avenella flexuosa*, ***Avenula pratensis***, *Berteroa incana*, *Calluna vulgaris*, *Carex humilis*, *C. supina*, ***Dianthus carthusianorum***, *Euphrasia stricta* agg., ***Festuca ovina* agg.**, *Gagea bohemica*, ***Genista pilosa***, ***Helichrysum arenarium***, *Hypericum perforatum*, *Iris arenaria*, *Jasione montana*, *Linaria genistifolia*, *Phleum phleoides*, *Pilosella echioides*, *P. officinarum*, *Potentilla verna* agg., *Pseudolysimachion spicatum* agg., *Pulsatilla grandis*, *Scleranthus perennis*, *Sedum rupestre*, *Silene otites* agg., ***Thymus praecox***

Constant species: *Acetosella multifida* agg., ***Achillea millefolium* s.l.**, ***Acosta rhenana***, ***Agrostis vinealis***, *Artemisia campestris*, ***Asperula cynanchica***, ***Avenula pratensis***, ***Carex humilis***, ***Dianthus carthusianorum***, ***Eryngium campestre***, ***Festuca valesiaca***, *Galium verum* agg., *Genista pilosa*, ***Hypericum perforatum***,

Koeleria macrantha* s.l.**, ***Phleum phleoides, *Pilosella officinarum*, *Pimpinella saxifraga* agg., *Plantago lanceolata*, ***Potentilla verna* agg.**, ***Pseudolysimachion spicatum* agg.**, *Sedum sexangulare*, *Seseli osseum*, *Silene otites* agg., ***Thymus praecox***

Dominant species: *Avenula pratensis*, *Carex humilis*, *Festuca ovina* agg., ***F. valesiaca***

These closed acidophilous grasslands are mostly dominated by *Festuca valesiaca* and *Avenula pratensis*. Besides the generalist species of dry grasslands numerous acidophilous and psammophilous species are present (e.g. *Acetosella multifida* agg., *Agrostis vinealis*, *Armeria vulgaris*, *Calluna vulgaris*, *Jasione montana* and *Trifolium arvense*). These grasslands occur in dry areas with acidic bedrocks (granite, gneiss, fluvial sediments) at the SE edge of the Bohemian Massif in SW Moravia and NW Lower Austria and in the area NE and W of Neusiedler See lake (Chytrý et al. 1997; Fig. 7). They are found on moderate slopes or flat surfaces with shallow rocky soil of ranker type. They were traditionally assigned to the alliance *Koelerio-Phleion phleoidis*.

Cluster 16. Dry grasslands on base-poor substrata

Syntaxonomical classification:

1. *Potentillo heptaphyllae-Festucetum rupicolae* (Klika 1951) Toman 1970
   Syn.: *Potentillo arenariae-Agrostietum vinealis* Chytrý et al. in Chytrý et al. 1997 (syntax. syn.), *Peucedano oreoselini-Festucetum rupicolae* Vicherek et al. in Chytrý et al. 1997 (syntax. syn.), *Astero linosyris-Festucetum rupicolae* Maglocký in Chytrý et al. 1997 (syntax. syn.)
2. dry grasslands of the *Festucion valesiacae* alliance with *Festuca pseudodalmatica* on base-poor volcanic substrata
3. *Festuco pseudovinae-Caricetum stenophyllae* (Bojko 1934) Wendelberger 1954 p. p. min.

Number of relevés: 135

Diagnostic species: ***Acetosella multifida* agg.**, *Acosta rhenana*, *Anthoxanthum odoratum*, *Arabidopsis thaliana*, *Armeria vulgaris*, *Arrhenatherum elatius*, *Berteroa incana*, *Bromus hordeaceus*, *Carex praecox* agg., *Jasione montana*, *Ornithogalum umbellatum* agg., *Peucedanum oreoselinum*, ***Potentilla argentea* agg.**, *Saxifraga bulbifera*, *Scleranthus polycarpos*, *Steris viscaria*, *Stipa borysthenica*, *Trifolium arvense*, *T. campestre*, *Valerianella locusta*, *Veronica arvensis*, *Vicia angustifolia*, *V. hirsuta*, *V. lathyroides*

Constant species: *Acetosella multifida* agg., *Acosta rhenana*, *Arrhenatherum elatius*, *Eryngium campestre*, ***Festuca rupicola***, *Galium verum* agg., *Hypericum perforatum*, *Koeleria macrantha* s.l., *Pimpinella saxifraga* agg., *Plantago lanceolata*, *Poa pratensis* agg., ***Potentilla argentea* agg.**, *Thymus pannonicus*, ***Tithymalus cyparissias***, *Trifolium arvense*, *T. campestre*

Dominant species: *Festuca pseudodalmatica*, *F. pseudovina*, ***F. rupicola***, *F. valesiaca*

This rather heterogeneous cluster links a few related vegetation types on acidic and base-poor volcanic substrata. Narrow-leaved tussock-forming fescues (*Festuca* spp.) dominate these grasslands. Some low-pH tolerant herbs (e.g. *Acetosella multifida* agg., *Jasione montana* and *Steris viscaria*) and species preferring calcium-poor soils are present. This vegetation occurs in areas with acidic bedrocks such as gneiss, granite and acidic sands. The majority of the relevés in this cluster contain *Festuca rupicola* as a dominant species; these correspond partly to the *Potentillo heptaphyllae-Festucetum rupicolae* association (SE edge of the Bohemian Massif, confluence of the Morava and Dyje rivers, NE Austria and SE slopes of the Malé Karpaty Mts; Chytrý et al. 1997: 24, Zlinská 2000, Michálková 2007b: 87; Fig. 7) and partly to acidophilous grasslands on quartzites at the SE edge of the Tríbeč Mts (W Slovakia). Eleven of the relevés in this cluster, which are dominated by *Festuca pseudodalmatica*, are from the volcanic areas of central Slovakia (Štiavnické vrchy Mts, Krupinská planina Plateau, Hronská pahorkatina Hills) and N Hungary (Börzsöny Mts). These grasslands contain some acidophilous species (e.g. *Acetosella*

multifida agg., *Potentilla argentea*, *Steris viscaria* and *Trifolium arvense*). Although they show some similarity to both *Inulo oculi-christi-Festucetum pseudodalmaticae* and *Alysso heterophylli-Festucetum valesiacae* associations (Michálková 2007b: 39), their phytosociological affiliation has not been sufficiently studied. Eight relevés dominated by *Festuca pseudovina,* which were assigned to this cluster, occur on non-acidic fluvial sands along the Danube river (Krippelová 1967) and Neusiedler See lake. They are very similar to the relevés included in cluster 17 and might be classified as *Festuco pseudovinae-Caricetum stenophyllae*. The vegetation included in cluster 16 is transitional between the alliances *Koelerio-Phleion phleoidis* and *Festucion valesiacae*.

Cluster 17. Dry grasslands with *Festuca pseudovina* on sandy soils

Syntaxonomical classification: *Festuco pseudovinae-Caricetum stenophyllae* (Bojko 1934) Wendelberger 1954 p. p. max.
Syn.: *Festucetum pseudovinae* Bojko 1934 (Art. 36), *Potentilletum arenariae* Bojko 1934 (Art. 36), *Festucetum pseudovinae potentillosum arenariae* Soó 1938 (Art. 3d), *Potentillo-Festucetum pseudovinae* Soó (1938) 1940 (Art. 2b), *Potentillo-Festucetum pseudovinae* Soó 1940 (Art. 2b), *Potentillo arenariae-Festucetum pseudovinae* Soó 1955 (syntax. syn.)

Number of relevés: 31
Diagnostic species: *Achillea millefolium* s.l., *A. pannonica*, *Carduus nutans*, ***Carex stenophylla***, *Cerastium semidecandrum*, ***Cynodon dactylon***, *Dactylis glomerata* agg., *Erodium cicutarium*, ***Erodium moschatum***, ***Festuca pseudovina***, *Holcus mollis*, *Lolium perenne*, *Lotus corniculatus* agg., *Medicago lupulina*, ***Melilotus officinalis***, *Muscari neglectum*, *Nonea pulla*, *Ononis spinosa*, *Petrorhagia saxifraga*, *Pilosella officinarum*, *Plantago lanceolata*, *Poa bulbosa*, *Polygonum aviculare* agg., *Salvia austriaca*, *Scorzonera cana*, ***Taraxacum* sect. *Erythrocarpa***, *T.* sect. *Ruderalia*, ***Tithymalus seguierianus***, *Trifolium campestre*, *T. pratense*, *Veronica prostrata*, *Viola rupestris*
Constant species: *Achillea millefolium* s.l., *A. pannonica*, *Cynodon dactylon*, *Dactylis glomerata* agg., *Eryngium campestre*, ***Festuca pseudovina***, *Lotus corniculatus* agg., *Pilosella officinarum*, *Plantago lanceolata*, *P. media*, ***Potentilla verna* agg.**, *Salvia pratensis*, *Sanguisorba minor*, *Veronica prostrata*
Dominant species: *Achillea millefolium* s.l., ***A. pannonica***, ***Carex stenophylla***, *Cerastium pumilum* agg., *C. semidecandrum*, *Cynodon dactylon*, *Dactylis glomerata* agg., *Erophila verna* agg., ***Festuca pseudovina***, *Galium verum* agg., ***Pilosella officinarum***, *Plantago lanceolata*, ***Potentilla verna* agg.**, *Saxifraga tridactylites*, *Thymus glabrescens*

These short dry grasslands occur on flat surfaces or gentle slopes on base-rich fluvial sands along large water bodies (Neusiedler See lake: Bojko 1934, Danube river: Krippelová 1967; Fig. 8). Besides the dominant fescue (*Festuca pseudovina*) some other species may also dominate, e.g. *Carex stenophylla*, *Achillea pannonica* and *Potentilla verna* agg. Generalist species of dry grasslands are accompanied by species preferring sandy habitats (e.g. *Carex stenophylla*, *Cynodon dactylon* and *Poa bulbosa*) and numerous vernal ephemeral annuals (e.g. *Cerastium* spp., *Erodium* spp., *Erophila verna* agg. and *Muscari neglectum*). The vegetation is species-poor and contains disturbance tolerant species, which are associated with intense grazing. This vegetation is also recorded in the Hortobágyi-puszta region in Hungary (Soó 1938, 1940, 1955). Originally these stands were meadows with slightly salinized sandy soil, but later they dried-out and were used for grazing.

Cluster 18. Pastures with *Festuca pseudovina* and species of hay meadows

Syntaxonomical classification: *Alopecuro pratensis-Festucetum pseudovinae* Juhász-Nagy 1957
Syn.: *Festucetum pseudovino-rupicolae* Řehořek 1969 ms. (Art. 1), *Festucetum pseudovino-rupicolae* Řehořek 1971 (Art. 2b, 3b)

Number of relevés: 91

Diagnostic species: ***Acetosa pratensis***, *Achillea millefolium* s.l., *Agrostis capillaris*, ***A. stolonifera***, ***Alopecurus pratensis***, *Anthoxanthum odoratum*, *Bellis perennis*, *Campanula patula*, *Cardamine pratensis* agg., ***Carex hirta***, *C. muricata* agg., *C. pallescens*, ***Cerastium fontanum* agg.**, *Cichorium intybus*, *Cirsium arvense*, *C. canum*, *Daucus carota*, *Deschampsia cespitosa*, *Dianthus armeria*, ***D. deltoides***, *Equisetum arvense*, ***Eryngium planum***, ***Festuca pratensis***, ***F. pseudovina***, ***F. rubra* agg.**, ***Galium boreale* agg.**, *Glechoma hederacea*, *Gypsophila muralis*, *Inula britannica*, ***Jacea pratensis***, *Lathyrus pratensis*, ***Leontodon autumnalis***, *L. hispidus*, ***Leucanthemum vulgare* agg.**, ***Lolium perenne***, *Lotus corniculatus* agg., *Luzula campestris* s.l., ***Lychnis flos-cuculi***, ***Lysimachia nummularia***, *Lythrum virgatum*, *Medicago lupulina*, *Oenanthe silaifolia*, *Ononis arvensis*, *Phleum pratense*, *Plantago lanceolata*, *P. major*, *Poa pratensis* agg., *Polygala vulgaris*, *Potentilla argentea* agg., ***P. reptans***, ***Prunella vulgaris***, ***Ranunculus acris* agg.**, *R. polyanthemos*, *Rhinanthus minor*, ***Sanguisorba officinalis***, ***Stellaria graminea***, ***Taraxacum* sect. *Ruderalia***, *Tithymalus esula*, ***Trifolium bonannii***, *T. dubium*, ***T. pratense***, ***T. repens***, *Veronica chamaedrys* agg., ***V. serpyllifolia***, *Viola canina*, *V. pumila*

Constant species: *Achillea millefolium* s.l., *Alopecurus pratensis*, *Cerastium fontanum* agg., *Festuca pratensis*, ***F. pseudovina***, *Fragaria viridis*, *Galium verum* agg., *Jacea pratensis*, ***Lotus corniculatus* agg.**, *Pimpinella saxifraga* agg., ***Plantago lanceolata***, ***Poa pratensis* agg.**, *Potentilla argentea* agg., *Ranunculus acris* agg., *Taraxacum* sect. *Ruderalia*, ***Trifolium pratense***, ***T. repens***

Dominant species: *Anthoxanthum odoratum*, *Festuca pratensis*, ***F. pseudovina***, *F. rupicola*, *Trifolium pratense*

In these pastures dominated by *Festuca pseudovina* numerous mesophilous meadow species are present (e.g. *Acetosa pratensis*, *Leucanthemum vulgare*, *Lychnis flos-cuculi*, *Ranunculus acris* agg. and *Trifolium pratense*). It is the most moisture- and nutrient-demanding of the vegetation types analysed (Fig. 3, 4). This type links the vegetation of *Festuco-Brometea* with the *Molinio-Arrhenatheretea* class (*Cynosurion cristati* alliance). It is rich in generalist species of dry grasslands, while the hay meadow species are less frequent. This species-poor vegetation usually dries out in late summer. It occurs at the edges of river floodplains or on mounds on the floodplains, which are not directly affected by ground water. Such grasslands were found in lowland parts of E Slovakia (Ružičková 1971) and in the Slaná river floodplain (Řehořek 1969), however, at many sites they were ploughed in the past. The *Alopecuro pratensis-Festucetum pseudovinae* association was originally described from the N part of the Alföld Lowland (Great Hungarian Plain, Juhász-Nagy 1957). The cluster includes also some previously heavily grazed grasslands on limestone bedrock in the karst areas of SE Slovakia (Drienčanský kras Mts: Kliment et al. 2000, Slovenský kras Mts) and volcanic bedrocks in central Slovakia (Neuhäusl & Neuhäuslová-Novotná 1964). In an earlier study (Michálková 2007b), based only on data from Slovakia, these stands were classified as the *Thymus pannonicus*-variant of the *Potentillo arenariae-Festucetum pseudovinae* association, which is a synonym of *Festuco pseudovinae-Caricetum stenophyllae*.

Cluster 19. Degraded steppes and abandoned arable fields on loess

Syntaxonomical classification: degraded type of *Salvio nemorosae-Festucetum rupicolae* Zólyomi ex Soó 1959

Number of relevés: 101

Diagnostic species: ***Achillea collina***, *Acosta biebersteinii*, ***Agrimonia eupatoria***, *Agropyron pectinatum*, *Artemisia vulgaris*, *Ballota nigra*, *Bromus inermis*, *Calamagrostis epigejos*, *Carduus acanthoides*, *Chenopodium album*, ***Colymbada sadleriana***, *Cynodon dactylon*, ***Dactylis glomerata* agg.**, *Daucus carota*, *Elytrigia repens*, *Erigeron acris*, *Falcaria vulgaris*, *Festuca pratensis*, *Galium verum* agg., *Gypsophila paniculata*, *Jacea pannonica*, *Lathyrus tuberosus*, *Linaria vulgaris*, *Linum perenne* agg., *Marrubium peregrinum*, *Medicago prostrata*, *M. sativa*, *Melampyrum barbatum*, *Nonea pulla*, ***Ononis spinosa***, ***Picris hieracioides***, *Pilosella auriculoides*, *Poa pratensis* agg., *Ranunculus polyanthemos*, ***Rubus fruticosus***, *Salvia aethiopis*,

S. nemorosa, *Securigera varia*, *Silene latifolia*, *Solidago canadensis*, ***Taraxacum serotinum***, *Tetragonolobus maritimus*, ***Tithymalus glareosus***, *Verbena officinalis*

Constant species: ***Achillea collina***, ***Agrimonia eupatoria***, *Asperula cynanchica*, *Bothriochloa ischaemum*, ***Dactylis glomerata* agg.**, *Eryngium campestre*, *Festuca valesiaca*, ***Galium verum* agg.**, *Koeleria macrantha* s.l., *Ononis spinosa*, *Picris hieracioides*, *Pimpinella saxifraga* agg., *Plantago media*, ***Poa pratensis* agg.**, *Scabiosa ochroleuca*, *Securigera varia*, *Taraxacum serotinum*, *Tithymalus cyparissias*, *T. glareosus*

Dominant species: *Bothriochloa ischaemum*, *Elytrigia intermedia* s.l., *Festuca pseudovina*, *F. rupicola*, *F. valesiaca*, *Galium verum* agg., *Leontodon hispidus*, *Poa pratensis* agg.

This cluster includes degraded steppes on loess occurring in the central part of the Pannonian Basin and the Mezőföld region in Hungary (Horváth unpubl., Kállayné Szerényi unpubl.; Fig. 8). Most sites of these grasslands were heavily grazed in the past or developed through secondary succession on abandoned fields, which is indicated by a high proportion of ruderal species (e.g. *Daucus carota*, *Erigeron acris* and *Picris hieracioides*). These grasslands can occur together with ones in a better conservation state, which are included in the next cluster (Fig. 5). The relevés of clusters 19 and 20 are very similar and most probably differ only due to land-use history (Zólyomi & Fekete 1994, Horváth 2002).

Cluster 20. Continental steppe grasslands with *Festuca rupicola* on loess

Syntaxonomical classification**:**

1. *Salvio nemorosae-Festucetum rupicolae* Zólyomi ex Soó 1959[2]
   Syn.: *Salvio (nutantis-nemorosae)-Festucetum sulcatae pannonicum* Zólyomi 1958 (Art. 3f, 34a, c), *Salvio (nutantis-nemorosae)-Festucetum sulcatae* Zólyomi ex Soó 1964 (Art. 3f , 34c); *Astragalo exscapi-Crambetum tatariae* sensu Mucina et Kolbek 1993 non Klika 1939
2. *Festuco valesiacae-Stipetum capillatae* Sillinger 1930 p. p. min.

Number of relevés: 192

Diagnostic species: *Agropyron pectinatum*, *Astragalus austriacus*, *A. onobrychis*, *Bromus inermis*, *Carex liparocarpos*, *Chamaecytisus austriacus*, *Chrysopogon gryllus*, *Colymbada sadleriana*, *Elytrigia intermedia* s.l., *Falcaria vulgaris*, *Galium glaucum*, *Hypericum elegans*, *Inula germanica*, *Linum hirsutum*, ***Salvia nemorosa***, *Seseli pallasii*, *Stipa capillata*, *Taraxacum serotinum*, *Thymus glabrescens*, ***Tithymalus glareosus***, *Viola ambigua*

Constant species: *Asperula cynanchica*, *Bothriochloa ischaemum*, *Elytrigia intermedia* s.l., ***Eryngium campestre***, *Festuca rupicola*, *Galium glaucum*, *G. verum* agg., ***Koeleria macrantha* s.l.**, *Medicago falcata*, *Plantago media*, *Poa pratensis* agg., *Pseudolysimachion spicatum* agg., ***Salvia nemorosa***, ***Stipa capillata***, *Teucrium chamaedrys*, *Thymus glabrescens*, *Tithymalus glareosus*

Dominant species: *Festuca pseudovina*, *F. rupicola*, *Stipa capillata*, *Teucrium chamaedrys*

The majority of relevés in this cluster represent species-rich Pannonian steppes of the association *Salvio nemorosae-Festucetum rupicolae* (Fig. 8). They occur on loess and are dominated by *Festuca pseudovina* and *F. rupicola*. Their species composition includes many continental species. The most typical stands occur in the Mezőföld region and hilly areas of N Hungary (Zólyomi 1958, Zólyomi & Fekete 1994, Horváth 2002, Illyés & Bölöni 2007). They are rich in the putative relicts of the Pleistocene loess steppe (*Agropyron pectinatum*, *Taraxacum serotinum*), loess preferring species (e.g. *Inula*

[2] Nomenclature note: Zólyomi (1958: 631) described the association *Salvio* (*nutantis-nemorosae*)*-Festucetum sulcatae pannonicum* Zólyomi 1958, although *Salvia nutans* was not present in the synoptic table of the original diagnosis. This name is invalid (Art. 3f) and illegitimate (Art. 34a). Soó (1959) proposed the name *Salvio-Festucetum sulcatae* for the same association based on the same original diagnosis. Due to to the absence of *S. nutans* in the original diagnosis, this name is interpreted here as *Salvio nemorosae-Festucetum rupicolae* Zólyomi ex Soó 1959 (*Festuca sulcata* = *F. rupicola*).

germanica, *Salvia nemorosa* and *Viola ambigua*) and Pontic-Pannonian species (e.g. *Colymbada sadleriana*, *Linum hirsutum* and *Tithymalus glareosus*). Some of these species reach their north-western distribution limit in S Moravia and the Wiener Becken Basin, however, they are rare and do not occur at every site with this vegetation. The cluster also includes relevés from S Moravia (*Stipa capillata*-dominated grasslands rich in species of continental steppe), which were mostly assigned to *Festuco valesiacae-Stipetum capillatae* by Chytrý et al. (2007), relevés from sandy soils in Marchfeld, Lower Austria (Schuster 1974), which were classified by Mucina & Kolbek (1993) as *Astragalo austriaci-Festucetum sulcatae festucetosum vaginatae* (Knapp ex Niklfeld 1964) Mucina in Mucina et Kolbek 1993 and relevés from Neusiedler See lake area.

Cluster 21. *Stipa tirsa* grasslands

Syntaxonomical classification: *Stipetum tirsae* Meusel 1938 p. p. max.
Syn.: *Stipetum stenophyllae* Podpěra 1930 (Art. 2b), *Campanulo-Stipetum tirsae* (Meusel 1938) Soó 1971 (Art. 22), *Inulo hirtae-Stipetum tirsae* (Baráth 1964) Borhidi 1996 (syntax. syn.)

Number of relevés: 46
Diagnostic species: *Adonis vernalis*, *Avenula compressa*, *A. praeusta*, *Calamagrostis epigejos*, *Campanula bononiensis*, *Chamaecytisus albus*, *Ch. austriacus*, *Colymbada sadleriana*, ***Crinitina linosyris***, *Danthonia alpina*, *Dianthus pontederae*, *Dictamnus albus*, *Echium russicum*, *Elytrigia intermedia* s.l., *Eremogone micradenia*, *Festuca rupicola*, *Filipendula vulgaris*, *Galium glaucum*, *Genista tinctoria*, *Hieracium umbellatum*, ***Inula ensifolia***, ***I. hirta***, *Lathyrus hirsutus*, *L. lacteus*, ***L. latifolius***, *L. pannonicus*, *Lembotropis nigricans*, *Linum flavum*, ***Peucedanum cervaria***, *Polygala major*, *Pyrethrum corymbosum*, *Rosa gallica*, *Scorzonera hispanica*, *Serratula radiata*, *S. tinctoria*, *Seseli pallasii*, *Stipa dasyphylla*, *S. pulcherrima*, ***S. tirsa***, *Trifolium alpestre*, *T. montanum*, *T. rubens*, ***Trommsdorffia maculata***
Constant species: ***Crinitina linosyris***, *Dianthus pontederae*, *Dorycnium pentaphyllum* agg., *Elytrigia intermedia* s.l., *Eryngium campestre*, ***Festuca rupicola***, *Filipendula vulgaris*, *Galium glaucum*, *G. verum* agg., ***Inula ensifolia***, *I. hirta*, ***Koeleria macrantha* s.l.**, ***Peucedanum cervaria***, *Salvia pratensis*, *Stipa tirsa*, ***Teucrium chamaedrys***, *Trifolium montanum*
Dominant species: *Festuca rupicola*, *Peucedanum cervaria*, *Stipa pulcherrima*, ***S. tirsa***

This cluster includes closed grasslands dominated mostly by the rare species *Stipa tirsa* (Fig. 8). Other rare species (e.g. *Echium russicum*, *Eremogone micradenia*, *Lathyrus lacteus* and *L. pannonicus*) are also frequently present. Some stands developed after abandonment of former vineyards and orchards established at sites of former oak forests, some others could be relicts of the lowland Pleistocene steppe. Besides species of dry steppe, this vegetation contains numerous species of meadow steppe. Sites with this vegetation are scattered on gentle slopes and foothills with relatively deep soils in colline landscapes of N Hungary (Baráth 1964, Less 1998, Garadnai unpubl.) and S Moravia.

Cluster 22. Dry grasslands with *Festuca rupicola* and *Carex humilis* on soft calcareous sediments

Syntaxonomical classification**:**
1. *Astragalo austriaci-Festucetum sulcatae* Soó 1957
2. successionally changed grasslands of *Festuco valesiacae-Stipetum capillatae* Sillinger 1930

Number of relevés: 114
Diagnostic species: *Adonis vernalis*, *Astragalus asper*, *A. austriacus*, *A. onobrychis*, *Bupleurum falcatum*, *Carex humilis*, *Colymbada scabiosa*, *Crinitina linosyris*, *Daphne cneorum*, *Dorycnium pentaphyllum* agg., *Festuca vaginata*, *Globularia punctata*, *Koeleria glauca*, *Potentilla verna* agg., *Scabiosa canescens*, *Seseli hippomarathrum*, *Stipa capillata*

Constant species: *Acosta rhenana*, *Asperula cynanchica*, *Astragalus onobrychis*, *Bothriochloa ischaemum*, ***Carex humilis***, *Colymbada scabiosa*, *Crinitina linosyris*, ***Dorycnium pentaphyllum* agg.**, *Eryngium campestre*, ***Festuca rupicola***, *Galium verum* agg., *Koeleria macrantha* s.l., *Pimpinella saxifraga* agg., *Plantago media*, ***Potentilla verna* agg.**, *Salvia pratensis*, *Scabiosa ochroleuca*, *Stipa capillata*, *Teucrium chamaedrys*, *Thymus glabrescens*, ***Tithymalus cyparissias***
Dominant species: *Carex humilis*, *Festuca pseudovina*, *F. rupicola*, *Inula ensifolia*, *Stipa capillata*

This heterogeneous cluster includes closed dry grasslands on deeply weathered calcareous bedrock (Leithakalk; Leitha Gebirge Hills), fluvial sands (surroundings of Neusiedler See lake: Schuster 1977, Koó 1994; Kis-Alföld Lowland: Borhidi 1956), loess and calcareous sandstone (S Moravia). The stands in Burgenland (AT) and Kis-Alföld Lowland (HU) are dominated mostly by *Carex humilis* and *Festuca rupicola*. They represent the *Astragalo austriaci-Festucetum sulcatae* association (Fig. 8). These grasslands typically contain species of dry habitats with deep sandy soils (e.g. *Astragalus* spp., *Carex liparocarpos*, *Daphne cneorum*, *Globularia punctata*, *Peucedanum oreoselinum* and *Tithymalus seguierianus*). The most typical stands of *Astragalo austriaci-Festucetum sulcatae* occur in the Kis-Alföld Lowland, where some continental psammophytes (e.g. *Festuca vaginata*, *Helichrysum arenarium*, *Iris arenaria* and *Koeleria glauca*) are abundant. Unfortunately most of these sites were ploughed in the past and only a few remain (Borhidi 2003). The sites in S Moravia represent vegetation of *Festuco valesiacae-Stipetum capillatae* that has successionally changed towards meadow steppe. They are dominated mostly by *Carex humilis* and *Stipa capillata*. Besides the generalists of dry grassland habitats, many species typical of the *Cirsio-Brachypodion pinnati* alliance (e.g. *Brachypodium pinnatum*, *Inula ensifolia*, *Pimpinella saxifraga*, *Plantago media* and *Scabiosa canescens*) are present.

Cluster 23. Dry grasslands in transition to Pannonian broad-leaved meadow steppe

Syntaxonomical classification: early stages of succession from the *Festucion valesiacae* grassland to *Polygalo majoris-Brachypodietum pinnati* Wagner 1941

Number of relevés: 121
Diagnostic species: *Adonis vernalis*, *Anemone sylvestris*, *Anthericum ramosum*, ***Aster amellus***, *Astragalus onobrychis*, ***Brachypodium pinnatum***, ***Bupleurum falcatum***, *Campanula glomerata* agg., *Carex halleriana*, *C. humilis*, ***Chamaecytisus ratisbonensis***, ***Colymbada scabiosa***, *Crinitina linosyris*, *Dictamnus albus*, *Dorycnium pentaphyllum* agg., *Festuca rupicola*, *Geranium sanguineum*, ***Inula ensifolia***, *Jurinea mollis*, *Knautia arvensis* agg., *Linum catharticum*, *L. tenuifolium*, *Onobrychis arenaria*, *O. viciifolia*, *Orchis militaris*, *Peucedanum alsaticum*, ***P. cervaria***, *Plantago media*, *Polygala major*, *Pyrethrum corymbosum*, *Rosa pimpinellifolia*, *Salvia pratensis*, *Scabiosa canescens*, *Scorzonera hispanica*, *Stipa joannis*, *Thesium linophyllon*, *Tithymalus tommasinianus*, *Vincetoxicum hirundinaria*, *Viola hirta*
Constant species: *Anthericum ramosum*, ***Asperula cynanchica***, *Aster amellus*, *Astragalus onobrychis*, ***Brachypodium pinnatum***, ***Bupleurum falcatum***, ***Carex humilis***, *Chamaecytisus ratisbonensis*, ***Colymbada scabiosa***, *Crinitina linosyris*, ***Dorycnium pentaphyllum* agg.**, *Eryngium campestre*, ***Festuca rupicola***, ***Inula ensifolia***, *Koeleria macrantha* s.l., *Medicago falcata*, ***Peucedanum cervaria***, *Pimpinella saxifraga* agg., *Plantago media*, *Potentilla verna* agg., ***Salvia pratensis***, *Sanguisorba minor*, *Scabiosa ochroleuca*, *Stachys recta*, ***Teucrium chamaedrys***, ***Tithymalus cyparissias***
Dominant species: *Carex humilis*, *Dorycnium pentaphyllum* agg., ***Inula ensifolia***

This cluster comprises open dry grasslands transitional between *Festucion valesiacae* and meadow steppes (alliance *Cirsio-Brachypodion pinnati*), which are frequently affected by landslides and soil erosion. Some stands developed as a result of succession from *Astragalo exscapi-Crambetum tatariae* (cluster 14). In later successional stages at abandoned sites, *Peucedanum cervaria* usually increases its cover. Most of these grasslands

occur on gentle slopes in the flysch hills of S Moravia (Vicherek & Unar 1971), on E foothills in the Alps and in the Wiener Becken Basin (e.g. Eichkogel and Bisamberg hills near Vienna: Seger 1975, Pfusterschmid 1998). It is assumed that at a later successional stage *Brachypodium pinnatum* may increase in cover and typical stands of *Polygalo majoris-Brachypodietum pinnati* may develop.

Cluster 24. Dry grasslands in transition to Carpathian broad-leaved meadow steppe

Syntaxonomical classification: transitions from the *Festucion valesiacae* grasslands to *Brachypodio pinnati-Molinietum arundinaceae* Klika 1939 and other types of broad-leaved meadow steppe

Number of relevés: 152

Diagnostic species: *Acinos alpinus*, *Anthericum ramosum*, *Anthyllis vulneraria*, *Arabis hirsuta* agg., *Asperula tinctoria*, *Aster amellus*, *Astragalus danicus*, *Betonica officinalis*, ***Brachypodium pinnatum***, ***Briza media***, *Bromus erectus*, *B. pannonicus* s.l., *Campanula glomerata* agg., *Carex caryophyllea*, ***C. flacca***, *C. michelii*, ***C. montana***, *C. tomentosa*, *Carlina acaulis*, *C. vulgaris* s.l., *Cirsium pannonicum*, *Colymbada scabiosa*, *Cruciata glabra*, *Dianthus carthusianorum*, *Festuca rupicola*, *Galium exoletum*, *Gentiana cruciata*, *Globularia punctata*, *Helianthemum nummularium* agg., *Hippocrepis comosa*, *Inula salicina*, ***Knautia arvensis* agg.,** *Koeleria pyramidata*, *Lathyrus pannonicus*, *Leontodon hispidus*, *Leucanthemum vulgare* agg., ***Linum catharticum***, *L. flavum*, *Lotus corniculatus* agg., *Molinia caerulea* agg., *Ononis repens*, *Pilosella bauhinii*, *Plantago media*, ***Polygala major***, ***Potentilla alba***, ***P. heptaphylla***, ***Primula veris***, ***Prunella grandiflora***, *Pulmonaria angustifolia*, *Rhinanthus minor*, *R. serotinus* agg., *Salvia pratensis*, ***S. verticillata***, *Sanguisorba minor*, *Serratula lycopifolia*, *S. tinctoria*, *Seseli annuum*, *Thesium linophyllon*, *Thymus pulegioides*, *Tragopogon orientalis*, *Trifolium medium*, *T. montanum*, *T. rubens*, *Trisetum flavescens*, *Veronica teucrium*, ***Viola hirta***

Constant species: *Anthericum ramosum*, *Anthyllis vulneraria*, ***Asperula cynanchica***, ***Brachypodium pinnatum***, ***Briza media***, *Carex caryophyllea*, ***Colymbada scabiosa***, *Dianthus carthusianorum*, ***Festuca rupicola***, *Galium verum* agg., *Helianthemum nummularium* agg., *Knautia arvensis* agg., *Koeleria macrantha* s.l., *Leontodon hispidus*, *Linum catharticum*, *Lotus corniculatus* agg., *Medicago falcata*, *Pimpinella saxifraga* agg., ***Plantago media***, *Polygala major*, *Potentilla heptaphylla*, *Pseudolysimachion spicatum* agg., ***Salvia pratensis***, ***Sanguisorba minor***, *Scabiosa ochroleuca*, ***Teucrium chamaedrys***, *Thesium linophyllon*, ***Tithymalus cyparissias***, *Trifolium montanum*, *Viola hirta*

Dominant species: *Carex humilis*, *Festuca rupicola*, *Inula ensifolia*

These transitions to species-rich meadow steppes occur on flysch and limestone bedrocks in S Moravia (Bílé Karpaty Mts: Sillinger 1929, Tlusták 1972), some mountain ranges of the Western Carpathians (Starohorské vrchy Mts: Janišová unpubl., Strážovské vrchy Mts, Tríbeč Mts), Inner-Carpathian basins in Slovakia (Turčianska kotlina Basin: Škovirová & Očka 2005, Zvolenská kotlina Basin, Žilinská kotlina Basin, Horehronské podolie Basin) and at scattered sites in more humid regions of Hungary (Fig. 5). Numerous mesophilous species of meadow steppe are diagnostic of this cluster. The way the data were selected resulted in similar relevés of *Brachypodio pinnati-Molinietum arundinaceae* from the Western Carpathians, dominated mostly by *Brachypodium pinnatum*, being excluded from the analysis.

Cluster 25. *Festuca rupicola* and *Carex humilis* dominated grasslands

Syntaxonomical classification**:**

1. *Festuco rupicolae-Caricetum humilis* Klika 1939
   Syn.: *Festuco sulcatae-Caricetum humilis* Klika 1936 (Art. 3f), *Festuco sulcatae-Poetum badensis* Jurko 1951 (syntax. syn.), *Campanulo sibiricae-Festucetum sulcatae* Michalko 1957 (syntax. syn.), *Fragario-Festucetum rupicolae* Bureš 1976 (syntax. syn.)
2. Transitions of dry grasslands (*Festucion valesiacae*) to hay meadows (*Arrhenatherion elatioris*)
3. Transitions of acidic dry grasslands (*Potentillo heptaphyllae-Festucetum rupicolae*) to meadow steppes and fringe vegetation

Number of relevés: 130

Diagnostic species: ***Agrostis capillaris***, *Anthoxanthum odoratum*, *Arrhenatherum elatius*, *Briza media*, *Calluna vulgaris*, *Danthonia decumbens*, *Daucus carota*, *Euphrasia stricta* agg., *Festuca rupicola*, *Fragaria vesca*, *Leontodon hispidus*, *Linum catharticum*, *Luzula campestris* s.l., *Pilosella officinarum*, *Plantago lanceolata*, *Potentilla heptaphylla*, *Thymus pulegioides*, *Trifolium ochroleucon*, *Viola mirabilis*

Constant species: *Achillea millefolium* s.l., *Arrhenatherum elatius*, *Asperula cynanchica*, *Eryngium campestre*, ***Festuca rupicola***, ***Galium verum* agg.**, *Hypericum perforatum*, *Koeleria macrantha* s.l., *Lotus corniculatus* agg., *Pilosella officinarum*, *Pimpinella saxifraga* agg., *Plantago lanceolata*, *P. media*, *Poa pratensis* agg., *Sanguisorba minor*, *Scabiosa ochroleuca*, *Teucrium chamaedrys*, ***Tithymalus cyparissias***

Dominant species: *Carex humilis*, ***Festuca rupicola***

The association *Festuco rupicolae-Caricetum humilis*, composed of generalist species of dry grasslands (see constant species of this cluster), is the least thermophilous type of vegetation included in the *Festucion valesiacae* alliance (Fig. 4). It is distributed throughout the study area from the warmer regions of the Pannonian Basin (Neuhäuslová-Novotná 1968) to the cooler Inner-Carpathian basins in Slovakia (Fig. 5, 8). Besides relevés of *Festuco rupicolae-Caricetum humilis*, the cluster also includes some relevés of dry grasslands in transition to hay meadows of the *Arrhenatherion elatioris* alliance (mostly in S Slovakia, Májovský 1958) and in transition from acidic dry grasslands of the *Potentillo heptaphyllae-Festucetum rupicolae* association, included in cluster 16 (Chytrý et al. 1997), to meadow steppes or fringe vegetation. These transitions are reflected in the diagnostic species list, which contains some species of hay meadows (e.g. *Arrhenatherum elatius*, *Leontodon hispidus* and *Plantago lanceolata*) and meadow steppes (e.g. *Briza media*, *Linum catharticum*, *Potentilla heptaphylla* and *Thymus pulegioides*).

Discussion

High-level syntaxa

The concept of two alliances of Carpatho-Pannonian dry grasslands, *Bromo pannonici-Festucion pallentis* and *Festucion valesiacae* (Mucina & Kolbek 1993, Borhidi 2003, Chytrý et al. 2007, Janišová et al. 2007), was supported in this study by their clear separation in a data set that covered the largest area of Central Europe in which this vegetation has ever been analysed. These two alliances represent specific habitats, which are well characterised by their diagnostic species.

In contrast, this study provides less support for the differentiation between the *Festucion valesiacae* and *Koelerio-Phleion phleoidis* alliances. Traditionally the separation of these two alliances is based on the presence/absence of acidophilous species and on bedrock type (Korneck 1974). The distribution of acidophilous dry grasslands within the study area reaches its highest extent on the SE margin of the Bohemian Massif in Moravia and Austria (Chytrý et al. 1997), but are not recognised in Hungary as a separate vegetation unit (Borhidi 2003). In E Austria and Slovakia *Koelerio-Phleion phleoidis* vegetation only occurs in small areas (Chytrý et al. 1997) due to the lack of suitable habitats. However, vegetation transitional between these two alliances occurs on base-poor soils in the volcanic areas of central Slovakia. It is possible that in the dry Pannonian region, *Festucion valesiacae* from base-rich soils and dry grasslands on acidic bedrocks are similar, while in the wetter regions of Western Europe these two vegetation types are more distinct (Korneck 1974). Since the data set analysed did not contain a representative propor-

tion of European acidophilous dry grasslands, we decided to follow here the traditional concept and maintain the *Koelerio-Phleion phleoidis* as a separate alliance, although we acknowledge that these stands are transitional to the *Festucion valesiacae* alliance.

In Hungarian phytosociological literature, the alliance name of *Festucion rupicolae* Soó 1940 corr. 1964 was used for steppe grasslands on deep loess (e.g. Borhidi 2003), which are found mainly in Hungary but also in S Moravia and in the Wiener Becken Basin in Austria. Regarding their species composition they are very similar to the dry grasslands on more shallow loess and rocky soils, which are traditionally assigned to *Festucion valesiacae*. For this reason we consider the alliances *Festucion valesiacae* and *Festucion rupicolae* as identical, and call them *Festucion valesiacae*, which is the older name.

The alliance *Asplenio septentrionalis-Festucion pallentis* (continental dry grasslands on volcanic bedrock dominated mostly by *Festuca pseudodalmatica*) was traditionally distinguished in Slovakia and Hungary (e.g. Soó 1973, Mucina & Maglocký 1985). Based on new taxonomical studies, *Festuca pseudodalmatica* Krajina is a tetraploid species, while *F. valesiaca* Gaudin is diploid (Fischer et al. 2005, Šmarda 2008). Plants of these two ploidy levels are very difficult to distinguish based on morphological characters in the field. Our results support the concept of associations traditionally included in *Asplenio septentrionalis-Festucion pallentis* (*Inulo oculi-christi-Festucetum pseudodalmaticae* and *Festucetum pseudodalmaticae*), but not of the alliance itself. Therefore, we include dry grasslands on volcanic bedrock in *Festucion valesiacae*. We also did not find support for separating dry grasslands on calcareous and volcanic bedrock into two suballiances, as proposed by Michálková (2007b).

Effects of the classification method used

TWINSPAN is a divisive technique, which starts with all relevés in a single cluster and in each step it successively divides clusters into two subclusters. Each division is based on a correspondence analysis of the relevés belonging to the cluster, and the cluster is divided along the midpoint of the first ordination axis (Hill 1979). This division algorithm caused the separation of some ecologically closely related relevés, which should be better classified within a single unit from the syntaxonomical point of view. This applies especially to clusters 12 and 13. TWINSPAN classification cannot be interpreted in the same way as a classification by cluster analysis, even though a modified algorithm, which produces any number of clusters (Roleček et al. 2009), was used. Clusters located on different TWINSPAN dendrogram branches are not necessarily less similar than clusters on the same branch.

A potential drawback of TWINSPAN and any other numerical method is some degree of misclassification of relevés to clusters. Misclassifications usually have negligible effects on synoptic tables or diagnostic species, which are determined statistically for individual clusters, because misclassified relevés make up a small proportion of the relevés in each cluster. However, misclassified relevés may appear on the distribution maps (Fig. 5) as isolated occurrences far away from the areas where most of the relevés of that cluster occur (Knollová et al. 2006). These isolated occurrences may indicate some degree of similarity of local vegetation to vegetation types that are widespread in other areas, but in most cases they should not be over-emphasized in interpretations of the distribution of vegetation types represented by particular clusters.

Marginal vegetation types and successional stages

Since the gradient of environmental conditions of dry grasslands is continuous, vegetation of the alliances studied is often in transition to ecologically similar vegetation types. Although we tried to avoid inclusion of relevés of grassland types other than the three target alliances in the analysis, relevés of vegetation in transition to other alliances were included. This is reflected in the species composition of some clusters. Cluster 1 represents transitions to *Sesleria*-dominated grasslands at low altitudes (*Diantho lumnitzeri-Seslerion*) and in the mountains (*Astero alpini-Seslerion calcariae*), clusters 10 and 25 include transitions to forest-fringe vegetation (*Geranion sanguinei*), cluster 18 links the vegetation of *Festuco-Brometea* with the *Molinio-Arrhenatheretea* class (*Cynosurion cristati* alliance), clusters 22, 23 and 24 include transitions to semi-dry grasslands or meadow steppes (*Bromion erecti* and *Cirsio-Brachypodion pinnati*), and cluster 25 transitions to hay meadows (*Arrhenatherion elatioris*). Unlike clusters that correspond to the core types of broadly recognized associations, these transitional types are difficult to classify in the syntaxonomical hierarchy.

The data set also contained successional stages of vegetation derived from the three alliances studied, usually occurring at abandoned, formerly grazed sites. In several cases they were not grouped in the same clusters as related successionally stable vegetation. These pairs of clusters are closely related (clusters 19 and 20; 9 and 10) but in some cases were located on rather remote branches of the classification dendrogram (Fig. 2; clusters 10 and 21; 23 and 14). Nevertheless, the branches of the TWINSPAN dendrogram can be rotated into arrangements that bring such remote clusters closer to each other. Vegetation of the basal Central European dry grassland association *Festuco valesiacae-Stipetum capillatae* is a special case. This floristically poorly separated association is present at many of the dry grassland sites in the study area. Its presence in five clusters (12, 13, 14, 20 and 22; the last is a successionally changed type) is due to minor variations in site conditions and management. Different association names were used for these ecological variants in the past, but due to lack of significant floristical differentiation, all of them are classified here within the broadly defined *Festuco valesiacae-Stipetum capillatae* association.

Local versus regional syntaxa

Many of the dry grassland vegetation units described in the past were based on data from small areas (see Mucina & Kolbek 1993, Chytrý et al. 2007, Janišová et al. 2007 for an overview). Applying some of these syntaxa to other areas can be difficult. The aim of this study was to detect associations valid at a broad geographical scale. The analysis did not support some local associations as they lacked diagnostic species or overlapped other earlier described associations. Therefore, they were included in broader associations.

It was shown that some locally described associations actually have large ranges (e.g. *Festuco valesiacae-Stipetum capillatae*, *Potentillo heptaphyllae-Festucetum rupicolae* and *Stipetum tirsae*), whereas other locally described associations proved to be well-defined units of local distribution (e.g. the NE periphery of the Pannonian Basin: *Campanulo divergentiformis-Festucetum pallentis*, *Poo badensis-Caricetum humilis*, *Allysso heterophylli-Festucetum valesiacae*; W fringes of the Western Carpathians: *Poo badensis-Festucetum pallentis*, *Festuco pallentis-Caricetum humilis*; Inner-Carpathian basins: *Orthantho luteae-Caricetum humilis*; the Dunántúli-középhegység Mts: *Seselio*

leucospermi-Festucetum pallentis, *Stipo-Caricetum humilis*; volcanites of the Inner Western Carpathians: *Inulo oculi-christi-Festucetum pseudodalmaticae*; the Danube River terraces: *Teucrio botryos-Andropogonetum ischaemi*; SE edge of the Bohemian Massif: *Avenulo pratensis-Festucetum valesiacae*).

Pairs of traditional associations that occur in the same geographical area were merged in clusters 3 (*Campanulo divergentiformis-Festucetum pallentis* and *Poo badensis-Caricetum humilis*), 4 (*Orthantho luteae-Caricetum humilis* and *Festuco pallentis-Seslerietum calcariae*), 5 (*Seselio leucospermi-Festucetum pallentis* and *Stipo-Caricetum humilis*) and 6 (*Festuco pallentis-Caricetum humilis* and *Poo badensis-Festucetum pallentis*) due to the similarity in their overall species composition in the large-scale comparative context. Nevertheless, at the local level, these pairs of associations do differ in their diagnostic and dominant species, physiognomy, structure and ecology, and are of value for local biodiversity monitoring (Janišová et al. 2007).

A large-scale syntaxonomical revision

Clusters obtained from the TWINSPAN classification do not match exactly with the associations that are traditionally recognized in the dry grasslands studied. Few clusters include only one association. We believe that it is not possible to classify a large data set with an agglomerative or divisive method and interpret the resulting clusters as associations according to the one-cluster-one-association rule. Agglomerative and divisive methods perform unsupervised classification, which considers only the information contained in a particular dataset (Bruelheide & Chytrý 2000, Kočí et al. 2003, Černá & Chytrý 2005, De Cáceres et al. 2009). Unsupervised classification is very useful for demonstrating patterns of compositional variation within a study area and given vegetation, and this is what was done in the current study. However, syntaxonomy attempts to create a system of vegetation units that goes beyond any study area, so the concepts of vegetation units used in the adjacent areas must be also considered. This is not the case in the unsupervised methods. Vegetation types with marginal occurrence in the study area are usually represented by few relevés in a data set, and therefore unsupervised methods do not unite them in a separate cluster. The same is true of local or rare vegetation types, which can be well differentiated based on species composition, but due to their limited representation in the data set do not form a separate cluster. Given these problems, we recommend to classify vegetation in two steps: (1) describe patterns in species composition using an unsupervised classification method; (2) produce formal syntaxonomy and develop an unequivocal formal definition for each association, using assignment criteria such as those used in the Cocktail method (Bruelheide 1995, 2000, Bruelheide & Chytrý 2000, Kočí et al. 2003). The present paper focuses on step 1, while step 2 remains a task for the future (although considerable progress has already been achieved at the national level for the Czech Republic and Slovakia; Chytrý et al. 2007, Janišová et al. 2007). The results presented in this paper should facilitate future progress, because the TWINSPAN clusters are compared with all the associations recognized in the most recent national vegetation handbooks (Mucina & Kolbek 1993, Borhidi 2003, Chytrý et al. 2007, Janišová et al. 2007) and it is shown which of these associations from different countries are similar or identical. Some nomenclature issues of the association names are also resolved.

However, the association *Cleistogeni-Festucetum pallentis* Csiky in Borhidi 2003, which is reported from the calcareous sandstone cliffs in the Medves Mts (N Hungary, Borhidi 2003), was not evaluated here because only a single relevé for it is published (Borhidi 2003: 250). Also, our data set did not include relevés of the *Festuco pallentis-Aurinietum saxatilis* Klika ex Čeřovský 1949 corr. Guterman & Mucina 1993 (rocky grasslands on acidic bedrocks) or relevés dominated by *Sesleria heuffleriana*, *S. hungarica* and *S. sadleriana*. Other associations traditionally classified in the class *Festuco-Brometea* (Mucina & Kolbek 1993, Borhidi 2003), *Sempervivetum soboliferi* Korneck 1975 and *Asplenio septentrionalis-Melicetum ciliatae* Kovács et Máthé 1964, include early-successional vegetation on limestone or volcanic rocks with succulents, chasmophytes, mosses and a few xerophilous herbs (Kovács & Máthé 1964); therefore we include them in the *Sedo-Sclerantethea* (*Koelerio-Corynephoretea*) class. None of these vegetation types were evaluated in this study.

Conclusions

Our analysis made use of national phytosociological databases (e.g. Chytrý & Rafajová 2003, Hegedüšová 2007, Lájer et al. 2008) and provides the first international survey of dry grassland vegetation in a natural biogeographical region of the Western Carpathians and adjacent lowland and hilly landscapes of the northern Pannonian Basin. Supported by recent detailed national surveys of dry grasslands in the Czech Republic and Slovakia (Chytrý et al. 2007, Janišová et al. 2007) and extensive field sampling in Hungary (Illyés & Bölöni 2007), this study provides a common framework for linking the previous schemes of vegetation classification, which were made separately within each country and to a large extent lacked international compatibility (e.g. Mucina & Maglocký 1985, Moravec et al. 1995, Borhidi 2003). Our study provides an important step towards the final goal, which is the establishment of a formal, international syntaxonomical classification with all syntaxa defined using unequivocal decision criteria. Such a classification, linked with an expert system for syntaxa identification is needed for nature conservation on an international scale. In the absence of internationally standardized information, the European Communities have accepted vague habitat types such as "Sub-Pannonic steppic grasslands" (6240) and "Pannonic loess steppic grasslands" (6250) as Natural Habitat Types of Community Interest according to Annex I of the Habitats Directive (92/43/EEC), although such types have unclear delimitation and are not supported by data. We believe that the present, as well as previous international comparative studies of habitat diversity (e.g. Botta-Dukát et al. 2005, Illyés et al. 2007) can contribute to overcoming such problematic decisions from the past and to the establishment of well-founded standards for international habitat classification and subsequent effective inventory and monitoring of endangered habitats.

See http://www.preslia.cz for Electronic Appendix 1.

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Zhrnutie

V práci sú prezentované výsledky syntaxonomickej revízie xerotermných trávnatých porastov zväzov *Bromo pannonici-Festucion pallentis*, *Festucion valesiacae* a *Koelerio-Phleion phleoidis* v prirodzenom biogeografickom regióne Západných Karpatoch a severnej časti Panónskej kotliny. Použitý geograficky stratifikovaný súbor obsahoval 2686 fytocenologických zápisov z Českej republiky, Rakúska, Slovenska a Maďarska. Modifikovaná analýza TWINSPAN rozdelila dáta do 25 zhlukov, ktoré boli ďalej ekologicky a synaxonomicky interpretované. Prezentovaná syntaxonomická klasifikácia jednotlivých vegetačných typov zjednocuje a zjednodušuje doteraz používané syntaxonomické systémy, ktoré sa v jednotlivých krajinách značne líšili. Pomocou detrendovanej korešpondenčnej analýzy boli vyhodnotené gradienty prostredia, ktoré najviac ovplyvňujú variabilitu druhového zloženia študovaných porastov. Na interpretáciu gradientov boli použité korelácie s indikačnými hodnotami. Hlavný gradient korešpondoval s pôdnymi živinami a vlhkosťou, ktoré negatívne korelovali s pôdnou reakciou.

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